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THE PLANT DISEASE REPORTER

CROPS RESEARCH DIVISION

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

Volume 45 Number 6

June 15, 1961

Growth Through Agricultural Progress

The Plant Disease Reporter is issued as a service to plant pathologists throughout the United States. It contains reports, summaries, observations, and comments submitted voluntarily by qualified observers. These reports often are in the form of suggestions, queries, and opinions, frequently purely tentative, offered for consideration or discussion rather than as matters of established fact. In accepting and publishing this material the Crops Research Division serves merely as an informational clearing house. It does not assume responsibility for the subject matter.

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Paul R. Miller

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PLANT DISEASE REPORTER
Epidemiology Investigations, Crops Protection Research Branch
Plant Industry Station, Beltsville, Maryland

THE PLANT DISEASE REPORTER

Crops Research Division — Plant Industry Station, Beltsville, Maryland
Volume 45 — June 15, 1961 — Number 6

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CONTROL OF DISEASES AND INSECT PESTS OF CROP PLANTS IN THE SOVIET UNION[1]

Robert R. Herr[2]

Preface

An extremely large portion of the world's potential harvest from food and industrial crops is destroyed each year by plant diseases and insect pests. The Food and Agriculture Organization of the United Nations has estimated that correctly organized plant protection could increase the yield of all crops on a worldwide basis by 20% at a cost not exceeding 6% of the value of the total yield. In recent years the Soviet Union has placed great emphasis on the importance of increasing agricultural output to meet domestic and export requirements. One of the most practical ways of increasing production is the reduction and prevention of losses caused by diseases and insect pests of crop plants. It is this area of Soviet agricultural research and development with which this article is concerned.

The following material represents a summarization of the pertinent facets of Soviet plant protection research and application as revealed by a survey of Soviet literature in this field. In addition, appropriate reports on Soviet agriculture, originating within the United States Department of Agriculture, have been reviewed. Of necessity only those references have been cited that are of major importance in supporting the general outline of the summary. Further background and supporting references are readily available in the U. S. Department of Agriculture Library, both in translated and original form.

INTRODUCTION

Control of diseases and insect pests of crop plants long has been recognized as an important problem by both Soviet agricultural scientists and political leaders. Crop losses as a result of the occurrence of diseases and insect pests are tremendous in the USSR. In 1955, an official Soviet estimate placed annual disease destruction at equivalent to 10% of the field crops (cereal, sugar, fiber, and tobacco crops), 20% of the vegetable crops, and up to 40% of the fruit crops (11). In 1960, the All-Union Institute of Plant Protection estimated that the annual value of additional agricultural production that could be achieved through more extensive plant protection would be "several tens of billions of rubles annually" (14). The Institute also estimated that the total losses sustained annually in Soviet agricultural production due to diseases, insects, and other pests of crop plants amounts to approximately 13% of the value of the total agricultural production of the USSR, including livestock. Excluding the value of livestock production from total production, on the basis of official Soviet data, crop loss from disease and insect pests would be 22% of total crop production (10).

The total cost of plant protection measures in the Soviet Union is not known, but in 1957 V. V. Kosov stated that "from the Union budget alone more than 180 million rubles were expended for the control of pests and diseases in 1956....Yet, the results ...lag behind that which is desired" (5). Much larger expenditures obviously will be needed to achieve a significant reduction of crop losses due to diseases and insect pests.

Official governmental support for extensive and improved programs for controlling disease and insect pests of crop plants is evident from the following portion of an editorial published in the official plant protection journal of the Ministry of Agriculture, USSR, in December 1959:

"In the resolution of the 21st Congress of the KPSS (Communist Party of the Soviet Union) it is written, that the control of pests, diseases, and weeds is an important reserve for the raising of total yields of agricultural production. The time has come to bring this reserve into action everywhere. We have all the conditions for this purpose. In many of the oblasts and republics, the measures for plant protection have acquired the virtue of law and have become compulsory for all the farms and individual citizens, who have plantings and sowings. An orderly State Service for Plant Protection is being strengthened from top to bottom; it is

[1]Owing to the nature of this article and to make all the information available to readers of the Plant Disease Reporter, an exception in editorial policy is made in publishing it, since its length exceeds our limit, and lack of source material has precluded the usual chemical identification of pesticides. -- Paul R. Miller.

[2]Graduate Student, Department of Botany, George Washington University, Washington, D. C.

being entrusted with the development of plans, with publicizing the foremost experience, with aiding the farms and with enforcing and carrying out the compulsory measures by all the kolkhozes, sovkhozes, and other farms. The basic method of plant protection is the use of chemicals, which, in various forms and methods, is carried out on a huge scale. Special chemical and machine-building factories have been and are being constructed for its accomplishment. With every passing year the quickly growing requirements of agriculture in effective chemical means and in highly productive tractor, truck, horse-drawn motorized and other dusters and sprayers, aerosol generators, soil fumigators, disinfecting and other machines are being more nearly satisfied. During the current year, chemical preparations are being released in large quantities--over 100 items: seed disinfectants, fungicides for green plants, insecticides, zoocides, bacteriocides, herbicides and other means for the chemical protection of crop plants and over 30 brands of various special machines. Agricultural aviation has at its disposal hundreds of powerful airplanes, and in a series of regions a considerable number of helicopters for the chemical treatment of sown crops, orchards, vineyards, forests, and virgin lands" (1).

Undoubtedly this official support will result in future improvement of Soviet research and development on the control of diseases and insect pests of crop plants. The extent to which such improvement will be reflected in the total productivity of agricultural crops will be dependent to a considerable degree on governmental decisions in relation to industrial production. This problem is exemplified by the following quotation from an editorial in the May 1960 issue of the official Soviet plant protection journal:

"The problems, which were set by the 21st Congress of KPSS (Communist Party of the Soviet Union), on increase of production of agricultural commodities, urgently requires further improvement of the service of plant protection, of conducting systematic measures in this area.... The success of the job, to a great degree, depends on the further provision of agriculture with reliable and sufficiently effective means of protection. Agricultural workers have a right to appeal to the chemical and machine-building industries, to the planning and administrative organizations, and, first of all, to the Gosplan (State Planning Committee of the Council of Ministers of the USSR) and to leaders of Sovnarkhozes (Councils of the National Economy) with the request to satisfy in a short time the needs in effective means for chemical control of pests and diseases of plants...., in highly-productive and technically precise machines and apparatuses for applying these substances" (2).

In general, it appears that the Soviets have been more concerned with the control of insect pests than with the control of diseases. This may be due in part to the greater publicity given to the necessity for insect pest control and to the fact that insects and insect damage are readily detected by rural workers while diseases frequently are overlooked completely unless damage is severe. One of the problems of the Soviet Government is to educate personnel at the farm level about the seriousness of losses the agricultural economy suffers, particularly as the result of diseases, and about the reduction of these losses that can be achieved through effective control (4).

The problem of plant disease and pest control in the Soviet Union is generally considered within the overall framework of plant protection. The most important research institute concerned with plant protection is the All-Union Institute of Plant Protection (VIZR), which is subordinate to the All-Union Academy of Agricultural Sciences imeni V. I. Lenin (VASKhNIL). This Institute is primarily responsible for the entomological, plant pathological, and applied plant protection research throughout the Soviet Union, functioning as both a controlling and coordinating center (12).

Although both basic and applied research is conducted by the institute, emphasis is on research and development that can be directly applied to practical control of agriculturally important diseases and insect pests. Basic research in mycology and bacteriology, as related to plant diseases, and, to a lesser extent, plant pathology is conducted by various institutes under the Academy of Sciences, USSR, and the republic academies of sciences. This is true also of basic entomological research which is conducted principally within the Institute of Zoology of the Academy of Sciences, USSR, and within certain academies of sciences at the republic level (17).

The Soviet Union has a comparatively large supply of entomologists; the All-Union Entomological Society, as of 1959, had a membership of 1460 (3). The portion of this number of members that is concerned directly with agricultural entomology is not known. Soviet entomologists have devoted extensive efforts to studies and experimental investigations in insect ecology, insect physiology, insect morphology, taxonomic entomology, insect behavior, and on the effect of climate on insect fauna (15). Soviet entomological research in its more de-

scriptive aspects is generally of good quality. Thus, basic research applicable to control of insect pests of agricultural crops appears to be adequate in the USSR.

The number of professionally trained and presently active plant pathologists is estimated to be 1900 to 2000.

In contrast to research in entomology, Soviet plant pathology research since about 1940 has been oriented toward the applied aspects of disease control, while basic research for the most part has been seriously neglected. Soviet literature on phytopathological research over the past two decades has reflected an extreme lack of research in such basic areas as the physiology of the pathogenic organism, the genetic relationships of host and pathogen, the physiology of host-parasite interactions, and the epidemiology of plant diseases (including production and liberation of inoculum, dissemination of plant pathogens, and the effect of environment on the development of epidemics) (18). Lack of research in these and other basic areas and preoccupation with applied aspects of disease control have seriously hampered the overall progress of Soviet research and achievements in this field. Much reliance is placed on the adoption of Western accomplishments to Soviet practice. Even so the lack of basic knowledge of specific phenomena and principles as they may operate under Soviet conditions hinders the success of such adoption.

CHEMICAL CONTROL

General

A report published in 1958 in a U. S. journal and written by an official of the Ministry of Agriculture, USSR, stated that chemicals play a decisive role in protecting agricultural crops in the USSR against diseases and insects. In 1957 approximately 390,000 tons of pesticidal chemicals were utilized, compared with only 53,000 tons in 1940. Although most of this tonnage was utilized for insect control, it was emphasized that extensive use had been made of fungicides for treating seed and for controlling diseases in growing crops (6).

Crop Plant Disease Control

The chemical control of diseases of crop plants has reached a high degree of development during the past 50 years. The development of effective fungicides for use as protective sprays and dusts and for seed and soil treatments has enabled agricultural scientists and producers in the United States to increase the annual production of many crops from 10 to 30%. Many crops require some form of chemical protection against disease for normal production. Frequently chemical treatment for disease control not only increases the yield, but also greatly improves the quality of the product and reduces the chances of later deterioration in storage. The Soviet Union, while participating in this development, has not attained the level of achievement evident in advanced Western countries.

Fungicides: Although Soviet scientists have shown high interest during the past two decades in the development of more effective fungicides for the control of diseases of crop plants, only a limited quantity of research has been conducted on synthesis of new compounds. Furthermore, much of the fungicide work that has been carried out through the research and synthesis stage has never reached the stage of practical utilization. The result has been that, with few exceptions, the fungicides utilized in the Soviet Union are similar to older and frequently even obsolete chemicals previously developed in the United States and other Western countries. Soviet fungicide research efforts have just recently begun to reflect the effects of U. S. fungicide research and development on high-potency organic fungicides. These fungicides are now being widely used in the United States whereas the limited research on them in the USSR is only beginning to reach the developmental stage.

Seed Treatment for Disease Control: In the USSR, much research attention has been given during the past two decades to seed treatment for control of seedborne diseases. Most seedborne diseases of agricultural crops yield readily to treatment with various fungicides. Although many different crop seeds can be treated effectively with disease control chemicals,

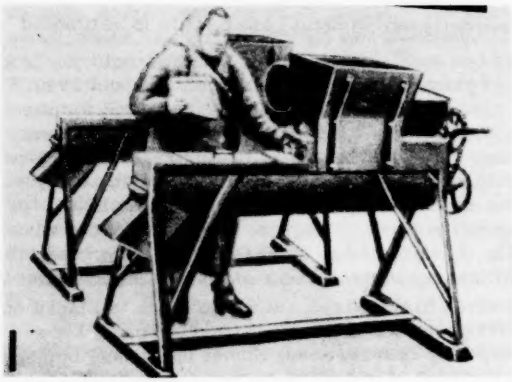

FIGURE 1. Soviet seed treatment machine PU-1, designed in 1946.

FIGURE 2. PU-1 seed treatment machine in operation.

FIGURE 3. Soviet farm workers utilizing hand-operated knapsack sprayers in control of a grape disease.

the seeds of the cereals and cotton are the chief objects of seed disinfection in the USSR.

Chemical treatment of seeds for the control of certain seedborne diseases has been one of the most successful and economic applications of chemical crop protection in U. S. agriculture. By contrast, in the USSR, seedborne diseases, particularly of cereal crops, remain one of the most serious sources of disease losses. This has been the result not only of insufficient quantities of fungicides and highly effective chemicals, but also because of inadequate quantities (or capacities) of seed treating machinery. Figures 1 and 2 show a Soviet seed treatment machine.

Certain seedborne diseases cannot be effectively controlled by surface treatment with fungicides because the pathogen is within the tissues of the seed. The loose smuts of wheat and barley are prime examples of this. Grain seeds infected with these organisms must be treated thermally (usually in the form of hot water treatment) or anaerobically (by placing water and seed within a hermetic container) in order to kill the fungus within the seed. Although thermal

treatment of wheat and barley seed for loose smut control has long been known and practiced, Soviet wheat and barley crops are still threatened annually with epidemics of loose smut, particularly in the new and virgin land areas. This, among other things, indicates a lack of treatment installations and equipment.

Antibiotics for Disease Control: Attempts to use antibiotic substances derived from fungi and bacteria, which heretofore had been used principally in human and veterinary medicine, for plant disease control began as early as 1946 in the United States. Subsequently, intensively conducted research with a wide variety of antibiotic compounds has opened a promising new approach to the control of plant diseases. Soviet plant pathologists were quick to follow up on U. S. exploratory work with investigations of their own and, as early as 1949, reported the results of their experiments on the reaction of certain plants to antibiotics. These early Soviet studies were concerned principally with absorption by the plants, translocation, assimilation, toxicity, and duration of inhibitory activity. From experiments on the use of antibiotics for disease control, the Soviet concluded that antibiotics are generally more effective against bacterial than against fungal pathogens. Soviet research scientists have given primary attention to the use of antibiotics to control certain bacterial diseases of fruits, cotton, and tomatoes. Frequently, unrefined cultural filtrates from various actinomycetes are used by the Soviets rather than purified or semi-purified standardized antibiotics. There is no evidence of commercial production of antibiotics specifically for plant disease control in the Soviet Union.

More recently, Soviet researchers have considered the use of antibiotics for control of fungal pathogens of plants. Experiments with the use of the antibiotic griseofulvin against a fungus attacking certain fruits and vegetables have been reported. Screening of other antibiotics against specific fungal pathogens is being conducted on a small scale (9). No extensive field experimentation with antifungal antibiotics for plant disease control has been reported in the USSR. Although of limited utility, the antibiotic Acti-dione (cycloheximide), which is antifungal in its action, has been available commercially for several years in the United States. Several other antibiotics including streptomycin have been tested widely in the United States for the control of fungal plant diseases.

A major advantage of some antibiotics used for plant disease control is their property to act systemically; that is, their characteristic to be absorbed by the plant and to be distributed within the vascular system. Once the compound is within the tissue of the plant, it can kill the pathogens as they enter. Soviet scientists have long been aware of the systemic action of certain antibiotics, but little research effort has been expended on clarification of this action or on its practical exploitation.

The systemic action of certain antibiotics falls into one of the major areas of research effort in the U. S. plant disease control program, that of plant chemotherapy. Such research now has extended beyond the use of systemic antibiotics to the development of synthetic chemotherapeutants by the so-called tailoring or modification of fungitoxic molecules for systemic activity. No Soviet research and development on synthetic chemotherapeutants is known at the present time.

Phytoncides for Disease Control: Soviet agricultural scientists have devoted surprisingly extensive research efforts to the study of antimicrobial substances derived from higher plants, which they term "phytoncides." Soviet research in this area, for the most part, has been crude, even unscientific. Although such antimicrobial substances have been under study in the USSR since the early postwar years, they have not been developed to any practical stage in the control of plant diseases.

Control of Plant Nematodes: Plant pathogenic nematodes (threadworms) have been given adequate recognition as pests of crop plants only within the past 10 to 15 years. Frequently these soil inhabiting organisms reduce crop yields extensively without recognizable symptoms on the aboveground part of the plants. Although Soviet research on the taxonomy and life histories of nematodes has been of good quality, research on chemical control of crop-attacking nematodes has been poor in quality and low in quantity.

In contrast to the low level of Soviet research on the control of crop-attacking nematodes, U. S. nematology has undergone an extensive development since 1943. Expansion of the science of nematology and the conspicuous success in the control of these pests in the United States took place as a result of several important developments: (a) discovery of inexpensive and practical control chemicals for field use; (b) improvement of techniques for demonstrating and

establishing nematode pathogenicity; (c) recognition of the significance of the nematode problem by scientists and agriculturists; and (d) the subsequent justification for training of a greater number of nematologists (13). None of these developments has occurred in the USSR, and the impact of U. S. achievements has not substantially influenced Soviet nematology.

Control of Virus Diseases: One of the serious problems affecting the productivity of certain crops in the Soviet Union is the high prevalence of virus diseases. This is particularly true of the potato crop. Qualified Western observers have noted that in Soviet potato fields, including those at Elite Seed (Growing) Stations in the USSR, virus infection occurred on an average of 25% of the plants (16). At present, no effective methods for direct chemical control of virus diseases of crops have been developed anywhere in the world. Using virus-free seed and propagative stock and controlling insect vectors have both proved useful against certain virus diseases in Western countries. Virus resistant varieties have also proved effective. As of 1958, the Soviets had no seed certification program in effect that could guarantee virus-free planting materials. The use of serological or chemical methods, indicator plants, and other methods for detecting virus infections in plants and planting materials for this purpose is believed to be poorly developed in the USSR. Some attention has been given in the USSR to chemical control of insect vectors of plant virus diseases but extremely little effort has been devoted to the development of resistant varieties. This low state of research on control of virus diseases is attributed by Soviet researchers to be partially due to the erroneous views of the Lysenkoists about the nature of certain virus diseases of plants. These views have recently been rejected as erroneous by leading Soviet plant virologists. It is believed that future research in this area will gradually improve.

Crop Plant Insect Pest Control

Over the past two decades, Soviet officials have placed strong emphasis on measures for improving the control of agricultural insects. During that time, the importance of insect control has received widespread publicity in the USSR. The Soviet Government has long recognized that large crop losses are caused by insects and that widespread utilization of better control methods and materials will increase the yields of crops.

In the USSR, insecticides are the major means of control of agriculturally important insects (1), but because of a lack of adequate amounts, cultural and biological control methods have also been strongly emphasized in Soviet insect control programs. Insecticides that are in actual practical use and considered of value in the USSR include many inorganic compounds that are considered obsolete in the United States. Of the organic insecticides, DDT and benzene hexachloride (technical grade BHC) are relied upon in the USSR even though supplies of these compounds still are not adequate. Organic phosphate insecticides are gaining in usage in the USSR but represent an extremely minor portion of total insecticides utilized. There are indications that certain chlorinated hydrocarbon insecticides used commercially in the United States (aldrin, chlordane, dieldrin, endrin, heptachlor, and toxaphene) have been under experimental study in the USSR (17). In general, the number of modern, high-potency organic insecticides available in the USSR in practical or usable quantities is very limited and the supply is grossly inadequate for Soviet needs.

Although the organic phosphate insecticides parathion (Thiophos), mercaptophos [demeton] (Systox), and methyl parathion (methyl thiophos or Vofatox) are being utilized for the control of agricultural insect pests in the USSR, there is scant information on the amounts being utilized. Fragmentary reports indicate that 208 tons of organic phosphate insecticides were utilized in the Uzbek SSR (primarily on cotton) in 1958 and that plans called for the application of an estimated 800 tons in that same republic in 1959 (8, 17).

Methyl thiophos is apparently not being produced in the USSR but is imported from East Germany under the trade name of Vofatox (similar to the West German E-605) (17).

For several years Soviet chemists have reported research on the structure and biological activity of a number of systemic insecticides. The development and, at least, small scale production of mercaptophos (Systox) is considered highly important by the Soviets. This systemic insecticide is being utilized to an increasing extent on cotton in the USSR; yield increases of 30 to 50% were reported (7).

Experimental (pilot plant) production of two new organic phosphate insecticides, K 2035 and Avenin, developed through the research of A. V. Kirsanov, was reported in 1959. Both of these compounds were found to be effective and specific for the control of the sugar beet weevil (17).

For several years Soviet chemists have reported research on the synthesis of organic

FIGURE 4. Aerial spraying of vineyards in Moldavian SSR.
FIGURE 5. Soviet Ka-15 helicopter, adapted for crop spraying.

phosphorus compounds suitable for use as insecticides. Studies on the structure and biological activity of organic phosphates with systemic activity have reflected superior work and many of the chemicals synthesized have not been described elsewhere. Thus, Soviet failure to be well advanced in the practical use of organic phosphate insecticides probably stems from causes other than lack of technical knowledge of their synthesis and manufacture.

Soil fumigants, such as formalin, chloropicrin, and carbon disulfide, have long been used in the USSR for control of insects in the soil. The number of highly effective fumigants available to Soviet agriculture has been limited until recently. During the past few years many of the new organic compounds have been tested as soil fumigants, but the extent to which they are being utilized in the USSR is not known.

CHEMICAL APPLICATION EQUIPMENT

The availability of reliable, efficient, and modern equipment for disseminating insecticides and fungicides has limited the control of diseases and pests of crops in the USSR. Soviet application equipment ranges from relatively crude, hand-operated (Fig. 3) or horse-drawn types to aircraft dusting and spraying equipment (Figs. 4 and 5). Much of the terrestrial application

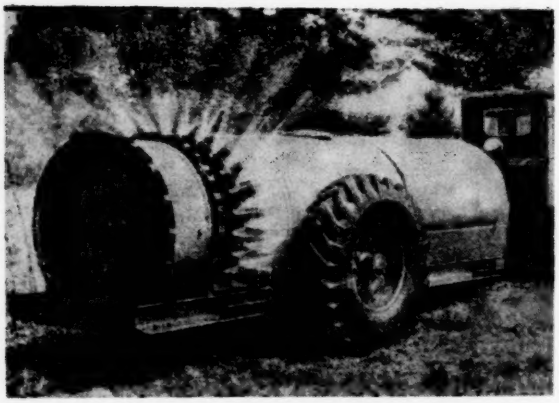

FIGURE 6. Experimental Soviet blower sprayer similar to modern U. S. speed sprayer.

equipment available in any quantity at present is obsolete and poorly engineered and constructed with resultant uneconomical, inefficient application of the chemical. Soviet aerial application equipment is quite similar to that utilized in other countries. The use of aircraft for the application of control chemicals has been increasing rapidly in the USSR and is expected to continue to expand at a steady rate (17). The large-scale farming units make aerial application more economical, and the importance of aerial treatment is enhanced by the lack of adequate quantities and the low productivity of present Soviet terrestrial application equipment.

In recent years, the USSR has begun to exploit more fully the advanced application equipment utilized abroad. Many Soviet experimental models based on foreign-designed equipment incorporating modern principles are presently being tested and undergoing approval for adoption and production in the USSR. (See example in Fig. 6).

TOXICOLOGY AND HYGIENIC PRACTICES

The Ministry of Health, USSR, has overall responsibility for pesticide toxicology and hygenic practices in application. Chemicals applied to crops are tested by the Ministry for degree of toxicity and permissible residue limits; consideration is given to problems of contamination of air, water, and soil; and certain specific substances are studied for possible carcinogenicity. On these bases, certain overall rules and regulations applicable to the country as a whole have been promulgated. These rules and regulations are further subdivided into specific and detailed directions and precautions to be followed by the users in agricultural practice and by persons handling the pesticides. Although sound rules and precautions have been formulated, fairly widespread violations of these rules apparently occur in Soviet agricultural practice. Stricter enforcement is being sought as the scale of chemical control is being increased in the USSR.

BIOLOGICAL CONTROL

During the past 20 years, Soviet plant pathologists and agricultural scientists have emphasized the possibility of controlling soil-borne diseases of plants by the use of microorganisms antagonistic to the disease pathogen. Soviet experimental research in this area has been more extensive than perhaps that of any other country but has been of comparatively low quality. Much of the Soviet research in this area is repetitive of research in certain Western countries. Evidence from such research is sufficient to indicate that certain soil-borne pathogens can be controlled, under experimental conditions, through the action of antagonistic microorganisms. Considerable success has been achieved in the United States in the control of Texas root rot of cotton through the use of green manure crops that provide large quantities of organic matter for the soil and thus favor the growth of certain microorganisms having an antagonistic effect on the Texas root rot organism. The Soviets, however, have not seriously attempted to solve the problems involved in the practical application of biological control of soil-borne plant diseases in the field. Thus, while the utilization of antagonistic microorganisms for the control of certain plant diseases appears to have a sound basis, the actual practical application under farming conditions remains a distant goal of Soviet research.

Among the many factors that adversely affect every insect species in the struggle for existence are the other living things that feed upon it. These natural enemies can be utilized by man to destroy or suppress the pest species. The use of this type of biological control was conceived as early as the 17th century. One of the problems which precludes the widespread use of biological control lies in the fact that nature's balance between certain destructive insects and their parasitic enemies permits too much crop damage to meet standards of modern production efficiency.

Biological control of insect pests of crop plants has received considerable publicity in the USSR and advantages over chemical methods have frequently been claimed. The Soviet Union has a relatively long history of biological control of insect pests but the majority of successful or partially successful methods applied in the USSR have been first developed abroad.

The problem of stimulating natural reproduction of parasites and predators by agrotechnical, cultural, and other means is presently being studied in the USSR. This research has dealt with the effect of depth of soil tillage on the survival of populations of insect parasites and predators, as well as with the use of cover crops to increase the size of such populations.

The use of microorganisms to control harmful agricultural insects also has long been of interest to Soviet scientists and many experimental attempts of microbiological control have been reported. The effectiveness of such attempts under field conditions has been very disappointing to Soviet researchers. Fungi have been the primary organisms utilized by the Soviets; relatively little research has been reported on the use of bacterial or virus diseases for insect pest control. New Soviet research is being conducted on the use of insect pathogenic microorganisms in combination with insecticides. This research is based on the idea that the effectiveness of microbiological control is much greater if the insect is first physiologically weakened by the use of small (sub-lethal) quantities of insecticide. Although this research is in its early stages, indications are that the simultaneous action of insecticides and pathogenic microorganisms is more efficient than the action of either controlling agent used separately (17).

Despite the extensive publicity given to biological control of insect pests in the USSR and despite the great significance of such control for the Soviet Union, biological control efforts have not been particularly extensive or of high quality. Research in this area has recently become more intensive and the breadth and quality of such research has gradually improved.

In summary, research on biological control of insect pests of crop plants in the USSR has attained only limited practical or economical significance and is less advanced than that which has been conducted in the United States. Such research will probably continue in the USSR at an accelerated rate with a gradual improvement in quality.

CULTURAL AND MECHANICAL MEASURES

Cultural and mechanical methods and practices for controlling insect pests in the USSR are of considerable importance considering the lack of adequate quantities of modern pesticides and equipment for their application in the Soviet Union. Mechanical measures, such as physical collection or removal of insects and the use of screens, nets, traps and barriers, and cultural measures based on crop rotation, soil tillage, variation in plantings, and harvesting dates and fertilization rates, have been extensively utilized in the Soviet Union over the past several decades. In general, these methods are suitable where unskilled farm labor is readily available and where standards of losses in quality and quantity of agricultural products are rather low. Over the past two decades, considerable Soviet research has been expended on the development of these methods and their adaption to particular situations. Some of the cultural methods developed and utilized are scientifically and economically sound, while others give poor returns for the efforts expended. Mechanical methods generally give poor returns. Soviet research on these methods of control is continuing but at a gradually reducing rate. As the Soviet supplies of modern control chemicals and improved application equipment increase, many of the low-return agricultural practices will be discontinued and the remaining sound practices will be used only to supplement other forms of control.

PLANT BREEDING FOR RESISTANCE

The ideal way to control most plant diseases and many plant insect pests undoubtedly would be by means of resistant crop varieties. Plant breeding for resistance has been a technique on which the Soviet Union has placed some reliance with varying success over the past two decades. The relatively limited development of crop plants highly resistant to insect pests and

diseases in the USSR is the result of at least two major factors: 1) the restrictive influence of Lysenko's genetic doctrines, and 2) the lack of cooperative research between plant pathologists, entomologists, agronomists, horticulturists, and plant breeders.

Recent direct observations of Soviet agricultural research by competent U. S. observers (16) indicate the following status of Soviet breeding research on disease resistant varieties for specific crops:

Wheat: The principal diseases against which the Soviets are attempting to breed resistant varieties are leaf rust, stripe rust, stem rust, loose smut, and stinking smut. The lack of and the need for such resistant varieties was readily apparent to the U. S. observers. Leaf rust was present in every field of wheat observed with 60 to 100% of the crop infected and the severity ranging from 5 to 100%. In some years, commercial fields and even nursery material reportedly suffered heavy losses from stripe rust. Stem rust infection was fairly general but light. Loose smut occurred commonly and breeding for resistance has been only partially successful. Stinking or covered smut control relied principally on chemical seed treatments.

Oats: This crop is used primarily as a feed crop and little varietal improvement is being attempted. Varieties now grown are resistant to most major diseases except crown rust and smut. Little interest has been shown in breeding for stem rust resistance.

Barley: There is only a limited amount of selection and breeding work with barley. As a result, leaf rust infection is almost universal and loose smut infection is common.

Rye: There is little evidence that an adequate rye breeding program has been developed. This may be due in large part to the fact that diseases do not cause a major reduction in rye yields in the USSR even though leaf rust is common and ergot is a problem.

Corn: Diseases do not seem to be a major factor in Soviet corn production at the present time, but problems in regard to both diseases and insects are developing in new areas of corn planting. The capabilities of Soviet corn breeders indicate a considerable potential toward meeting these problems.

Sugar beets: Varieties are available which possess a rather high degree of resistance to the major diseases of this crop.

Potatoes: Virus diseases are widespread due to lack of resistant varieties and disease-free seed potatoes. Late blight is particularly damaging to the potato crop. The development of varieties resistant to this disease is considered the most urgent problem of Soviet potato breeders. Only a few of the present "resistant" varieties of potatoes are actually resistant to the highly virulent races that occur in the USSR.

Sunflower: Some varieties have been developed that are resistant to rust, a major disease, and experimental lines possessing downy mildew resistance have been developed.

Cotton: Although cotton yields are fairly high, the actual incidence of and damage from cotton diseases apparently is greater than the Soviets generally recognize. Fusarium wilt is common and breeders are attempting to find a source of resistance to this disease.

Perhaps the most serious of the various weaknesses in Soviet breeding for disease-resistant plants, from a long-range point of view, are the lack of research on races of pathogens and failure to consider the effects of environment on disease resistance. In the United States, it has become almost axiomatic that tests of varieties for disease resistance should be made against an adequate sample of all known virulent biotypes or races of the pathogen against which breeding is directed, and under an adequate sample of environmental conditions, particularly those that favor maximum disease development. In the absence of such procedures, varieties presumed to be resistant may frequently be attacked unexpectedly by new races of the pathogen or by old races under new conditions. A knowledge of physiological races of the pathogen is a prerequisite to the adequate and thorough testing of resistant varieties. The establishment of disease nurseries in which epidemics are created artificially also is becoming a necessary requirement for adequate testing of resistance.

Soviet plant pathologists and plant breeders concerned with developing disease-resistant varieties have almost entirely disregarded the two factors of physiologic specialization and environmental effects. While the problem of physiologic specialization in rust races is recognized by Soviet workers, little research has been done during the past 10 years on identification of rust races. The recent revelation by the Soviets that many of their so-called resistant potato varieties are actually susceptible to aggressive races of Phytophthora infestans present in the USSR gives further indication of lack of research on physiological races and their relation to disease resistance. It appears that the problem of the effect of the environment on disease resistant varieties and the pathogen involved also is ignored to a considerable extent by Soviet scientists, because such varieties are recommended for Union-wide planting without sufficient testing in varied geographical locations or without the utilization of nurseries designed

to test susceptibility to disease (18).

There is probably no more economical or more desirable way to control insect pests than through the use of plant varieties that resist insect attack. In recent years, U. S. scientists have engaged in exhaustive searches for resistant varieties and in the breeding of resistant characteristics into otherwise desirable varieties. Such research and development has been an important phase of U. S. crop improvement programs and has been productive and promising. In contrast, breeding for insect resistance in the USSR has not been accorded the same relative research effort, and is usually considered secondary to the development of cold hardiness and disease resistance (17).

Little information is available on the specific insects against which the Soviets are seeking to develop plant resistance, although they are devoting some attention to resistance against the Swedish frit fly (Oscinella frit) and the Hessian fly in cereals. Some experimental work on developing resistance to the Colorado potato beetle has been reported also.

SURVEY, FORECASTING, AND WARNING SERVICE

Plant disease and insect pest survey, forecasting, and warning service of the USSR is the direct responsibility of the Department of Quarantine and Plant Protection under the Ministry of Agriculture, USSR. Methodological direction and compilation of data is the responsibility of the All-Union Institute of Plant Protection. Approximately 820 institutions or organizations are involved in servicing Soviet agriculture with long and short-term forecasting and with surveys of occurrence of diseases and insect pests of crop plants. The present system of surveying and forecasting, the extensiveness of the reporting network and formulative units, and the total magnitude of the effort is relatively new to the USSR. Prior to the improvement of the system (up to 1957), a Soviet analysis of the operations indicated that disease and pest forecasting was at an extremely low state. Even under the new system, plant disease forecasting is poorly developed and, as a consequence, this is reflected in the overall picture of the quality of disease control. Surveying and forecasting methods in regard to insect pests of crop plants are of a higher level than those in relation to diseases of crop plants in the USSR. The methods employed appear to be similar to those commonly used in the United States and elsewhere, with the exception that considerably more emphasis is given by the Soviets to the physiological condition of insects in forecasting outbreaks and occurrences. The status of Soviet plant disease and insect pest surveying, forecasting, and warning service presents an uneven picture: the extensiveness of the network involved and the means to implement inclusive and extensive measures are impressive; but the actual practical contributions made toward achievement of improved disease and insect pest control are unimpressive. Gradual improvement in this practical contribution can be expected in the near future, as the techniques of the service improve and as greater reliance on and incorporation of the results into practice are achieved at the farm level.

QUARANTINE MEASURES

Quarantine measures are of great importance to the protection of crops in the USSR from many plant diseases and insect pests not present or present only in limited areas within the USSR. Plant quarantine is directed by the Department of Quarantine and Plant Protection of the Ministry of Agriculture, USSR, through a special all-union quarantine service and the intermediary of agricultural organizations in the republics. The quarantine activities and methods utilized in the USSR compare favorably with those employed elsewhere in various countries throughout the world. In recent years, the USSR has become increasingly interested and active in international cooperation in the quarantine field; such participation in international quarantine should be of advantage to the Soviet quarantine program.

The Soviet Union is an active, cooperative member of the "European and Mediterranean Plant Protection Organisation" and recently established with China the "Moscow-Peking Conference."

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CADANG-CADANG DISEASE OF COCONUTS IN GUAM MAY BE CAUSED BY A SOIL-BORNE PLANT VIRUS SPREAD BY DAGGER NEMATODES (XIPHINEMA SP.)

O. A. Reinking[1] and J. D. Radewald[2]

Two dagger nematodes, Xiphinema americanum Cobb, 1913 and Xiphinema diversicaudatum (Micoletzky, 1927) Thorne, 1939, were found in soil about the root systems of coconuts in areas with 100% infestation of infectious yellow mottle decline (Cadang-Cadang) disease. These findings may open an entirely new approach to the cause and control of the disease.

The senior writer, in a 2-month investigation of the decline disease of coconuts on the Island of Guam, established that the disease there is identical with or similar to the Cadang-Cadang (yellow mottle decline) disease in the Philippines (1, 3, 4, 10, 12). The cause of the disease in the Philippines is suspected to be a virus. Transmission experiments conducted in the Philippines from 1949 to date by scientists of the Bureau of Plant Industry and the College of Agriculture, University of Philippines at Los Banos have not been successful in transmitting the disease experimentally (1, 3, 9, 11).

During 1957-59 virologists sent by the Food and Agriculture Organization of the United Nations, Rome to the Philippines to advise on investigations of the disease, including Drs. W. C. Price, F. P. McWhorter and Karl Maramorosch, share the opinion of most Filipino investigators that the disease is of a virus nature (9, 11). Price concluded that "The evidence in favor of the virus hypothesis is very strong whereas evidence against it is very weak. So long, however, as the disease cannot be transmitted experimentally there will remain a doubt that it is a virus infection."

XIPHINEMA

In so far as the writers have been able to determine from published data, all transmission studies conducted in the Philippines have been with flying insects. Because of the slow rate of field spread, it has been suggested that it is possible that an insect not well adapted to feeding on coconuts might be a vector. In any event, no transmissions have been made. No mention has been made that the cause, if a virus, may be one of the soil-borne plant viruses.

Harrison (5) summarized data on transmission of diseases by the large, migratory dagger nematodes of the genus Xiphinema. The fanleaf virus of grape was the first virus shown to be transmitted by a nematode, Xiphinema index Thorne and Allen (7). Xiphinema diversicaudatum has been established as a vector in the transmission of arabis mosaic virus to strawberry (8) and to pea (6). Another nematode, X. americanum, has been established as a vector of peach yellow-bud mosaic virus of peach (2). Harrison (5) stated that "The first three viruses found to be transmitted by eelworms all have species of Xiphinema as vectors, but several other eelworms seem equally well fitted to be vectors and it is to be expected that other soil-borne viruses, as yet without known vectors, will be transmitted by other genera."

In the soil about roots of severely diseased coconut trees with infectious yellow mottle decline, the following other parasitic nematodes were found: Helicotylenchus nannus Steiner, 1945, Rotylenchus sp., Aphelenchoides sp., Meloidogyne sp., and Rotylenchulus reniformis Linford, 1940. While these preliminary collections were small in number, no definite conclusions can be drawn as to possible relationship to coconut decline. It is clear, however, that parasitic nematodes, including Xiphinema sp., were present, apparently in larger numbers in the hundred percent infested coconut plantings as opposed to those with little or no disease.

All nematode determinations were made by the junior writer. As soon as studies of further soil nematode isolations have been completed, a detailed report of nematodes in relation to diseased areas will be presented.

The fact that thus far the possible vector of the Cadang-Cadang (yellow mottle decline) of coconuts has not been found might well indicate that the disease, if a virus, may well be caused by a soil-borne plant virus and transmitted by a parasitic nematode. Certainly transmission tests with the dagger nematodes (Xiphinema sp.) at least are warranted in further studies on Guam and in the Philippines. Such studies should be made in spite of the evidence that the disease spread in the Philippines seems to be erratic (1, 4) and may not appear to always spread from tree to tree. In the Philippine investigations some plots showed that, starting with one infected tree in the corner of a plot of 500 bearing trees, the next case of disease appeared in the opposite corner of the plot. Because of such results, it has been surmised that disease

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spread must be by some flying insect vector (1, 9, 11). In Guam, however, there are many instances in which trees in newly planted areas have developed disease symptoms in localized areas and the disease apparently is spread slowly from tree to tree.

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NEMATODES ASSOCIATED WITH CARNATIONS IN A SURVEY OF COMMERCIAL GREENHOUSES

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Several investigators (3, 7, 9) have shown that plant-parasitic nematodes are pathogenic to, or parasitic on, carnations. Nematodes are also capable of increasing the incidence of bacterial and fusarial wilts of carnations when present in the soil (6, 8). Since a previous survey of soils in commercial greenhouses where roses were grown demonstrated high populations of plant-parasitic nematodes (5), a survey was undertaken to determine whether a similar condition existed in greenhouses where carnations were grown.

A total of 166 soil samples and 94 root samples was obtained from 49 locations (growers) in 21 States (Table 1)[2]. The States sampled in the survey are illustrated in Figure 1. Where more than one sample was obtained from a grower they were from different areas in the greenhouse, usually from areas where the plants exhibited differences in vigor. Approximately 1 pound of soil, usually including the roots of the carnation plant, was obtained for each sample.

The soil for each sample was processed by roiling in a bucket of water and then running the mixture through 30- and 200-mesh sieves. The residue from the 200-mesh sieve was then processed by the modified Baermann funnel technique (1) and examined for nematodes. The roots in each of the 94 root samples were examined for root-knot nematodes (Meloidogyne spp.), processed in a blender for about 20 seconds, and washed through a 30-mesh sieve over a 200-mesh sieve. The residue from the 200-mesh sieve was examined directly for meadow nematodes (Pratylenchus spp.).

Data are presented (Table 1) for those nematodes considered either parasites or possible parasites[3]. Of the 166 soil samples 110 were positive for parasitic nematodes. Of the 49 locations, 9 had no parasitic nematodes in any of their soil or root samples; 31 had one or more samples without parasitic forms; and 9 had parasitic nematodes in all samples. Although carnations are known to be attacked by several species of root-knot nematodes (6, 8) none were found in any sample.

The nematodes found in the survey are listed (Table 1) in their probable order of importance as plant parasites. This order is based on the total number of samples in which a particular nematode was found and on the number of samples in which it was found in large numbers. Nematode populations were observed and rated in a Syracuse dish under a dissecting microscope at 20 magnifications. Each kind of parasitic nematode present was rated separately. The rating was "very heavy" when a particular nematode covered the bottom of the dish, with most specimens touching or overlapping; "heavy" when the nematodes covered the entire optical field and were close to each other; "moderate" when the nematodes were widely scattered over the entire field; "light" when there were only one to several in the field; and "one to several" when only one to several specimens occurred in the entire sample.

Free-living forms found were in the genera Acrobeles, Acrobeloides, Alaimus, Aphelenchus, Aporcelaimus, Cephalobus, Chiloplacus, Diplogaster, Dorylaimus, Eucephalobus, Labronema, Monhystera, Mononchus, (sub-genera Mononchus and Mylonchulus), Panagrolaimus, Prismatolaimus, Rhabditis, and Sectonema. No attempt was made to identify these as to species. Occasional specimens in the sub-families Neotylenchinae and Nothotylenchinae also were found.

No direct correlations were found in this study between the presence of plant parasitic nematodes and the unthriftiness of carnation plants or infection of carnation plants with other diseases. Carnations are known hosts for Paratylenchus and Criconemoides (3, 7, 9). Nematodes of the genus Tylenchorhynchus, although not known parasites of carnations, have been shown to be both parasitic and pathogenic for other hosts (4). Since all three genera frequent-

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[2]The author acknowledges his appreciation for the assistance received from Dr. Robert N. Stewart, Crops Research Division, Agricultural Research Service, in obtaining the samples from the various growers.

[3]The nematode species were identified with the aid of existing keys except for Paratylenchus of the P. curvitatus/projectus group for which definite species determination was felt to be impracticable. With the aid of the key to the species of Paratylenchus and the description of the species of P. dianthus (curvitatus) and P. projectus (2, 3), Paratylenchus in most instances fell in the P. curvitatus/projectus group. In many samples, however, the distinction was not clear and often specimens had characteristics of both species (annules on lip region and a spermatheca; specimens in the same sample with or without annulation of the lip region; annulation of the lip region with males present). There were also instances where nematodes seemed to belong to this group but where there was no post-vulval body-width reduction.

Table 1. Analysis of plant-parasitic nematodes in soils and carnation roots from commercial, carnation-growing greenhouses of 21 States.

Nematode	State																					Nematode population				
	Calif.	Colo.	Conn.	Idaho	Ill.	Ind.	Maine	Md.	Mass.	Mich.	Minn.	Mo.	N. J.	N. Y.	Ohio	Oreg.	Pa.	S. C.	Tenn.	Wash.	Wis.	Total no.	Very heavy	Heavy	Moderate	Light	1 to several
Number of growers	3	4	2	1	3	1	2	6	5	2	1	3	1	4	2	1	3	1	1	1	2	49					
Number of soil samples	20	9	5	1	9	4	4	13	9	9	4	14	4	12	15	12	10	1	2	5	4	166					
Number of root samples	8	5	2	1	4	4	0	11	6	8	4	12	0	12	2	6	3	1	2	0	3	94					
	Number of samples with nematode																						Number of samples				
Paratylenchus (curvitatus[a]/projectus)	10	-	1	-	3	1	1	6	1	8	-	8	2	4	5	7	7	1	1	4	1	71	-	6	15	28	22
Tylenchorhynchus dubius	-	-	1	1	-	-	2	-	2	1	-	-	-	5	-	-	2	-	-	1	-	15	1	6	3	2	3
Tylenchorhynchus sp.	-	-	-	-	1	-	-	2	-	-	-	3	-	-	-	-	3	-	-	-	-	9	-	2	1	1	5
Criconemoides sp.	-	-	-	-	-	-	-	3	-	-	-	-	-	1	-	-	1	-	-	-	-	5	-	1	-	2	2
Criconemoides curvatum	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	1	-	-	5	-	1	1	1	2
Criconemoides cylindricum	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	3	-	-	2	1	-
Scutellonema brachyurum[b]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	2	1	-	-	-	1
Helicotylenchus nannus	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	3	-	-	1	-	2
Helicotylenchus n. sp?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	1	-	-
Tylenchus minutus	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	2	1	-	-	-	-	4	-	-	-	4	-
Tylenchus costatus	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
Tylenchus filiformis	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
Pratylenchus sp.	-	-	-	1	1	-	-	1	-	-	-	-	-	2	-	-	1	-	-	-	-	6	-	-	-	2	4
Pratylenchus neglectus[c]	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-
Hoplolaimus tylenchiformis[d]	-	-	-	-	-	-	-	5	-	1	-	-	-	-	-	-	1	-	-	-	-	7	-	-	-	3	4
Psilenchus aberrans	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	1	-
Psilenchus sp.	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Paratylenchus hamatus	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2
Aphelenchoides sp.	3	-	1	-	4	-	-	2	1	-	-	1	1	1	-	-	-	-	-	3	1	18	-	-	-	1	17
Ditylenchus sp.	-	1	-	-	1	-	-	-	1	-	-	2	-	1	-	-	-	-	-	1	-	7	-	-	-	-	7

[a]Considered the same as Paratylenchus dianthus by Tarjan (1960).
[b]Considered the same as Rotylenchus brachyurus by Andrassy (1958).
[c]Considered the same as Pratylenchus minyus by Loof (1960).
[d]Considered the same as Hoplolaimus coronatus by Andrassy (1958).

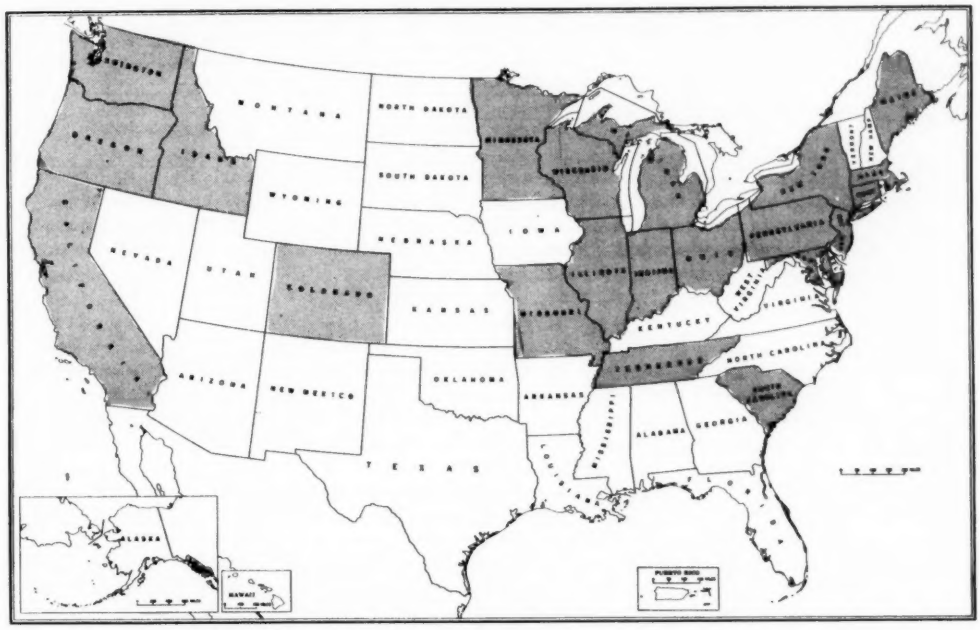

FIGURE 1. States sampled (in gray) in a survey of commercial, carnation-growing greenhouses.

ly occurred in high numbers in the present soil samples it would seem probable that Tylenchorhynchus, as well as Paratylenchus and Criconemoides, is parasitic on carnations.

Plant-parasitic nematodes are commonly found associated with carnations in greenhouse soils just as in commercial greenhouses growing roses (5). In most instances the carnation soils examined were reported to have been steamed or chemically treated. This probably explains why parasites were absent in approximately one-third of the samples.

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CITRUS VARIETY REACTION TO TRISTEZA VIRUS IN BRAZIL WHEN USED IN VARIOUS ROOTSTOCKS AND SCION COMBINATIONS[1]

T. J. Grant[2], Sylvio Moreira[3], and Ary A. Salibe[4]

Summary

All of the various citrus rootstock-scion combinations, cooperatively tested by the Instituto Agronomico and the United States Department of Agriculture for their reaction to tristeza virus in Brazil, were reviewed in 1960. The growth responses of varieties on tristeza-tolerant rootstocks, and the rootstock varieties found non-tolerant and unsatisfactory, are listed in this report.

INTRODUCTION

Wherever citrus is grown, tristeza and the reaction of citrus varieties to this disease are of interest. Varieties have been tested most extensively in scion and rootstock combinations at the Instituto Agronomico, Campinas, and at Limeira Citrus Experiment Station in Brazil. This work which is cooperative with the United States Department of Agriculture, Agricultural Research Service, has been in progress since 1946.

Several reports (1, 2, 3, 7) cover various aspects of the investigations, but none lists all the varieties tested. The present report lists varieties that survived the intensive inoculations with aphid vectors and summarizes the average growth response as indicated by circumference measurements of three trees 10 years after planting in the field. It also lists all the varieties found to be non-tolerant to the tristeza virus and unsatisfactory for use as rootstocks in Brazil.

METHODS

The detailed methods have been described previously (1, 3). Approximately 275 lots of citrus seed were sent from the United States to Brazil and each was assigned a field number. Seed collected in Brazil were also assigned numbers. Seedlings were grown in flats in a screenhouse, transplanted to clay pots, selected for uniformity of growth, and transplanted to a field nursery. In this nursery lots of five seedlings of each variety were separately top worked by budding with nucellar Valencia, Barao sweet oranges, Dancy tangerine, Foster or Duncan grapefruit and in some cases with West Indian lime or Eureka lemon. All plants in this nursery were subject to inoculation by means of three repeated transfers of 100 or more viruliferous Aphis citricidus (Kirk.) that had been fed on infected field trees known to contain the common or severe strain of tristeza virus. Three of the five plants of each variety top and rootstock combination that survived these drastic nursery tests were transplanted (1949-1951) to a field at the Limeira Citrus Experiment Station. The records of growth are based on circumference measurements in July 1960.

RESULTS

Growth of several different citrus variety tops, as measured by trunk circumference 10 cm above the bud union of the tristeza-tolerant citrus varieties used as rootstocks, is presented in Table 1. For convenience of presentation, the table is compiled according to a general grouping of the varieties and their related hybrids used as rootstocks such as mandarins, tangelos, sweet oranges, trifoliate hybrids, and miscellaneous. The order of listing the rootstock varieties within each group is based on the average for trunk-circumference measurements for all tops tested in descending order. The individual variety tops have average circumference figures based on only three trees for each rootstock. The reader should recognize that because tristeza is epidemic there was no possibility of comparing the growth of tristeza-infected trees with that of healthy, non-infected trees. The varieties that head each group list, however, are appreciably better than those at the bottom, and the differences may be due

[1]Initial tristeza virus inoculations and nursery testing carried out by A. S. Costa and T. J. Grant. Current field readings and analysis by authors.

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Table 1. Average circumference of 3 citrus trees on various rootstocks 10 cm above union 10 years after inoculation with tristeza virus and transplanting to a field, Limeira, Brazil[a].

Rootstock group and variety	Circumference (cm) for indicated top: Valencia orange	Barao orange	Dancy tangerine	Duncan grapefruit	Foster grapefruit	Avg
MANDARINS						
Sunki	73	63	--	--	--	67
Swatow (PI-14054)	73	57	--	--	--	65
Kara (Frost)	67	60	--	--	--	64
Rangpur lime	75	64	--	66	44	62
Nobilis (CPB-10642)	69	61	--	55	--	62
Cleopatra	70	61	64	48	57	60
Clementine	71	58	--	60	51	60
Suen Kat	73	50	--	62	54	60
Satsumelo (10-V-3)	63	57	--	--	--	60
Temple	74	57	--	51	54	59
Ponkan	69	53	--	55	--	59
Kinnow (Frost)	64	64	--	49	--	59
Mandarin (PI-114412)	66	59	63	40	62	58
Oneco	68	54	--	49	55	57
Mandarin (CPB-10630)	--	58	59	53	--	57
Mandarin (PI-117477)	67	58	51	54	48	56
Sun Chu Sha Kat	68	57	61	55	37	56
Swatow (CPB-10031)	--	56	--	--	--	56
Dancy	64	51	--	52	48	54
Swatow (CPB-10032)	--	53	--	--	--	53
Cowgill Marcott	--	53	--	--	--	53
Murcott Honey	56	56	--	39	--	50
Pook Ling Ming	57	56	50	46	35	49
Tangerine Cravo	--	49	58	36	--	48
King of Siam	46	58	50	46	37	47
Weshart	54	44	53	39	45	47
Calashu	49	37	50	50	--	47
Ling Ming	62	58	40	36	34	46
Chao Chou Tien Chieh	--	51	52	32	--	45
Kumembo	--	44	--	--	--	44
Satsuma	--	42	--	43	--	43
Tangor (653)	49	32	47	46	34	42
Average	64	54	54	47	46	54
TANGELOS						
Suwanee	65	67	--	57	--	63
Orlando	73	62	59	46	65	61
Sunshine	74	54	--	54	46	57
Minneola	64	58	--	--	50	57
Sampson	72	61	--	39	53	56
Williams	63	58	--	56	48	56
Tangelo (18-H-6)	--	48	63	58	--	56
Umatilla	61	48	--	--	--	55
Seminole	66	54	--	46	--	55
Webber	53	45	--	--	52	50
Yalaha	48	44	57	46	41	47
San Jacinto	49	43	46	47	47	46
Tresca x Dancy (126-5-17)	43	34	50	42	45	41
Average	61	52	55	49	50	53
SWEET ORANGES						
Hamlin	72	63	--	--	69	68
Parson Brown	69	64	--	53	--	62
Florida Sweet seedling	76	61	--	--	47	61
Pineapple	72	64	--	50	52	60

Table 1. (continued)

Rootstock group and variety	Circumference (cm) for indicated top: Valencia orange	Barao orange	Dancy tangerine	Duncan grapefruit	Foster grapefruit	Avg
SWEET ORANGES (con.)						
Navel	62	60	52	53	53	56
Homosassa	--	61	60	53	41	54
Caipira	48	54	53	55	--	53
Lue Gim Gong	59	39	52	54	45	50
Ruby Blood	62	54	53	39	37	49
Jaffa	--	58	--	37	--	48
Mediterranean	53	51	51	36	38	46
Valencia	--	54	--	36	43	44
Shamouti	49	36	50	46	33	43
Lamb Summer	52	17	54	51	43	43
Pera	31	49	55	38	41	43
Average	59	52	53	46	45	51
TRIFOLIATES						
Morton citrange	62	52	52	47	49	52
Troyer citrange	57	44	--	47	44	48
Citrumelo (PI-4475)	59	38	--	45	37	45
Rusk citrange	43	40	45	42	41	43
Uvalde citrange	--	51	42	36	38	42
Citrumelo (PI-4477)	--	41	--	--	--	41
Poncirus trifoliata (L.) Raf. (large flowered)	49	27	--	31	31	35
Citrumelo (PI-4482)	--	34	--	--	--	34
Cunningham citrange	36	30	32	34	34	33
Savage citrange	28	39	22	27	40	31
Average	48	40	39	39	39	41
MISCELLANEOUS						
Columbia Sweet lime	--	45	--	--	--	45
Sweet lime	56	42	--	--	38	45
Webber's Philippine hybrid (Kalpi)	36	27	--	34	--	32
Lima de Persia	39	34	47	37	25	36
Rough lemon (Fla.)	--	54	--	45	--	50
Rough lemon (Brazil)	--	39	--	39	--	39
Tiawanica Fla.	50	56	57	45	39	49
Average	45	42	52	40	34	42

[a]P.I. = U.S.D.A. Plant Inventory. CPB = Crops, Physiology and Breeding. E.E.L = Estacao Exp. Limeira, Brazil.

at least partly to the presence of tristeza virus. The poor growth of trees with grapefruit tops is related to the grapefruit tissues which are directly affected by the tristeza virus regardless of the tolerance of the rootstock.

Of the mandarins and hybrids used as rootstocks (Table 1), Rangpur lime, Sunki, Swatow, Kara, Nobilis, and Cleopatra have supported very good top growth of sweet oranges.

The tangelos that were tristeza-tolerant are listed in Table 1. The tangelos found to be non-tolerant of tristeza virus are listed in Table 2. The reaction of the tangelos (hybrids of tangerine x grapefruit) to the tristeza virus is of special interest because some react like mandarins and are tolerant, whereas others react like grapefruits and are non-tolerant. Growth measurements indicated there are varying degrees of tolerance among the tangelos. Suwanee, Orlando, Sunshine, and Minneola apparently are relatively very tolerant, whereas Webber, Yalaha, San Jacinto and a Tresca x Dancy hybrid are considerably less tolerant to the tristeza virus.

The sweet oranges as rootstocks are listed in Table 1. In the past the sweet oranges have been considered relatively tolerant to the tristeza virus and very good top growth was obtained when Hamlin, Parson Brown, Florida Sweet seedling, and Pinapple orange were used as rootstocks. In contrast, appreciably poorer growth was obtained with Pera, Lamb Summer,

Table 2. List of citrus varieties tested as rootstocks for Sweet orange and grapefruit tops which died or failed to make satisfactory growth following inoculation with the common severe strain of tristeza virus in Campinas, Brazil[a].

Rootstock Group and Variety		
	SOUR ORANGES	
Algiers Seville sour	Citrus aurantium var. myrtifolia Ker-Gawl.	Oklawaha sour
Arancia Bizzaria (CPB-7484-A)		Paraguay sour
Arancia Bizzaria (CPB-7484-D)	Daidai (PI-117471)	Rehoboth Palestine sour
Azeda sem esphinhos	Dummitt bittersweet	Spain sour
Bergamia sour	Dummitt sour	Sauvage sour (PI-128348)
Bigardier sour	Egyptian sour	Sour #2
Bittersweet Florida	Lanceta Amarga	Tunis sour
Bittersweet (Stow)	Limao Viradouro	
	LEMONS	
Amber (E. E. L.)	Eureka	Limao Gigante (E. E. L.)
Armstrong (E. E. L.)	Eureka (E. E. L.)	Limao Vicosa (E. E. L.)
Bernia	Genova (E. E. L.)	Lisboa (E. E. L.)
C. sp. (lemon CPB-10785)	Harris	Lisbon
C. sp. (lemon PI-126539)	Harvey	Meyer (thornless)
Cowgill	Kulu	Morocco
Cuban shaddock	Kusner	Punjab
De ba Ahmed	Lemelo	Siciliano (E. E. L.)
Dehra Dun	Lemon (PI-136469)	Vila Franca (E. E. L.)
Deodora (E. E. L.)	Lima Selvagem (E. E. L.)	Woglum
Des 4 Saison	Limao Doce (E. E. L.)	
	GRAPEFRUITS	
Duncan	Red Blush (Webb)	Ruby Red (Henninger)
Foster	Red Mexican	Thompson
Marsh	Royal	
	PUMMELOS	
Flemmings shaddock	Ogami pummelo	Toranja Chinesa
Hawaiian shaddock	Rangpur (X) Sour pummelo	Toranja Kau Paune
India Red pummelo	Siamese pummelo	Toranja Periforme
Nakon pummelo	Tau Yau pummelo	Zamboa
Natsu Mikan	Thong Dee pummelo	Zamboa (San Carlos)
	TANGELOS	
Pina	Tangelo (18-L-3A)	Thornton
Tangelo (16-I-4)	Tangelo (18-T-2)	Tresca (X) Dancy (126-5-19)
Tangelo (18-D-14)	Tangelo (18-U-13)	Tresca (X) Dancy (126-6-18)
Tangelo (18-E-7)	Tangelo (18-W-10)	Watt
Tangelo (18-I-8)	Tangelo (PI-52018-W-2F)	Wekiwa
Tangelo (18-I-13)		
	LIMES	
Beledy	Kirk	Limao Galego
Kadu Mul (Pink lime)	Lima de Umbigo	Limao Periforme
Key		
	KUMQUATS	
Calamondin	Lakeland limequat	Meiwa (E. E. L.)
Calamondin (E. E. L.)	Lemonquat (PI-48770)	Nippon
Fortunella crassifolia Swingle	Meiwa	Tavares limequat
	MISCELLANEOUS	
Citropsis	Limue Khargi	Severinia buxifolia (Poir)
Citrus sp.	Misri Batabi	Severinia buxifolia (CPB-11567)
Ichangensis lemon	Poorman orange	
Kansu		Severinia sp.

[a]P. I. = U. S. D. A. Plant Inventory. CPB = Crops, Physiology and Breeding. E. E. L. = Estacao Exp. Limeira, Brazil.

Shamouti, and Valencia orange as rootstocks. This indicated difference in tolerance of sweet orange varieties to tristeza virus has recently been emphasized by the occurrence of tristeza stem pitting symptoms on Pera orange in Brazil and Valencia orange in the African Congo. It is of interest that the Pera and Valencia orange varieties appear near the bottom of the rootstock list in relation to growth in the present studies.

The list of trifoliate orange hybrids is presented in Table 1. There were appreciable differences in top growth. The Morton and Troyer citranges as rootstocks produced very much better top growth of Valencia and Barao sweet oranges than did the Cunningham and Savage citrange.

The miscellaneous varieties listed in Table 1 are of general interest. The sweet limes as rootstocks required considerable time to show the effects of tristeza virus, but they do not now appear to have a very high degree of tolerance to the virus.

The Florida Rough lemon is considered to be tolerant to tristeza virus, but in the present tests the top growth on this rootstock was neither very good nor very poor.

Stem pitting is a symptom of tristeza that is expressed most severely in plants such as West Indian lime and grapefruits that have tissues sensitive to the severe strain of the virus. In general all the grapefruits inoculated as nursery plants with the severe strain showed marked depressions on the trunks and branches and an abundance of stem pits beneath the bark. Such trees produce compact branch growth with mineral-deficiency symptoms in the leaves and may have branch die-back. The fruits are small, thick-skinned, and very acid.

Some degree of stem pitting beneath the bark has been observed on all varieties. Recently in Brazil the Pera orange, which has been multiplied extensively, has shown not only pitting beneath the bark but also sunken areas on the trunks and branches of infected trees. The extreme cases of trunk pitting are believed to be caused by budwood sources carrying the severe strain, and those showing only pitting and twisting of individual branches are thought to be caused by spread of the severe strain by means of aphids.

DISCUSSION

Some growth differences may be due to genetic differences or to innate incompatibilities or factors other than tristeza. Likewise, some of the varieties tested, such as Temple orange and Clementine, produce only zygotic seedlings and are not satisfactory for use as rootstocks. These factors should be given consideration by the reader. In the present study seedling plants as uniform as possible were selected for the tests. Tolerance of the various citrus varieties to the tristeza virus is relative. The sour oranges are very non-tolerant and the sweet oranges and mandarins are relatively very tolerant. The data obtained, however, indicate all gradations of tolerance among the varieties listed. Even the sweet oranges and mandarins show gradations; for example, the reactions of Pera and Valencia orange in comparison with those of the Hamlin orange.

Since the beginning of this study there have been advances in our knowledge of the tristeza virus and we now recognize virus strains or mixtures (4, 5, 6, 8). These factors complicate the thinking concerning control of the disease under field conditions, but such knowledge is essential to a better understanding of virus spread and control under field conditions. The plant breeder developing rootstocks, for example, must aim at obtaining the greatest degree of tolerance to the severest virus strain or strain mixture. It is hoped that results of the present study may help to guide his choice of crosses.

The present results may also be of service in areas where tristeza virus has only recently, or not yet, been identified. Eventually scientists in these areas may be faced with the same problems experienced in Brazil and although the results given in this report cannot replace their experimental work, they may help to guide the approach to the problem.

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PATHOGENICITY OF THIELAVIOPSIS BASICOLA ON PEAS[1]

A. B. Lloyd and John L. Lockwood

Summary

In a survey of Michigan pea fields with root rot in 1960, Fusarium solani f. pisi was present in all of 19 fields sampled, and Aphanomyces euteiches was present in 14 of 25 fields sampled. Thielaviopsis basicola was isolated from diseased roots from 4 of 25 fields sampled. Pathogenicity of 10 isolates of T. basicola, based on a scale of increasing disease severity from 0-9, ranged from 1.7 to 5.5. The most pathogenic isolates caused a black-brown dry rot which completely destroyed the root cortex. In a field at East Lansing with severe root rot, T. basicola appeared to be the principal pathogen.

In 1955 and 1956 Lockwood, et al. (6) made systematic surveys of pea diseases in areas of Michigan where this crop is grown for the canning and freezing industry. They concluded that root rots were the most important group of parasitic diseases of peas. In Michigan and other pea-growing States, the important root rot pathogens appear to be Aphanomyces euteiches Drechs. and Fusarium solani f. pisi (F. R. Jones) Snyd. & Hans. Lockwood (4) and Lockwood and Ballard (5) in 1956 began a program of evaluating pea varieties and foreign introductions to obtain varieties of pea resistant to these two fungi. Selected lines of peas showing some degree of resistance in greenhouse tests were planted in a root rot field at East Lansing for further evaluation. Isolations made from these plants grown in the field in 1959 sometimes yielded Thielaviopsis basicola (Berk. & Br.) Ferr. (4). The fungus was shown to be pathogenic on peas.

T. basicola was first described by Berkeley and Broome in 1850 (1). The fungus was observed on the base of pea stems, and these authors considered it "either destructive of the plant on which it grows, or is developed on it in consequence of previous disease." In 1928 Linford (3) in a survey of pea fields in the United States reported T. basicola chlamydospores on the blackened surface of the roots of a few plants from a field in Idaho. The fungus is well known as a pathogen of tobacco, cotton and other plants, and is reported to have a host range of over 100 species, including peas (2).

As T. basicola is not generally considered part of the root rot complex of pea, a survey was made of Michigan pea fields in 1960 to determine the prevalence of this fungus. At the same time information was collected on the incidence of A. euteiches and F. solani f. pisi.

MATERIALS AND METHODS

The survey was made in five important pea-growing areas in Michigan: Caro, Saginaw, Croswell (all in the "thumb"), Montague (western Michigan), and Jackson (south-central Michigan), and also at East Lansing. Fields were visited 2 to 3 weeks before harvest, and samples were taken only from fields where root rot was observed. Sixteen plants with visible root rot symptoms were taken from each field sampled. Tap roots from eight of the plants were washed in running tap water, cut into nine transverse pieces, and surface-sterilized by immersion in 0.5% sodium hypochlorite for 5 minutes. The cut pieces were then washed in sterile water. Three of the sections from each root were placed on water agar, three on corn meal agar, and three macerated pieces were placed on carrot disks on moist filter paper in a Petri dish (7). Streptomycin at 100 μg per ml and chloramphenicol at 10 μg per ml were added to the agar to inhibit growth of bacteria. The remaining eight plants from each field were examined microscopically for the presence of chlamydospores of T. basicola and for oospores of A. euteiches.

Pathogenicity tests were made with isolates of T. basicola and F. solani f. pisi. Each isolated fungus was grown in potato-dextrose broth for 7 days at 24°C. The mycelial mats were washed in distilled water, ground in a Waring Blendor, and the homogenate mixed with autoclaved soil in 4-inch clay pots. Pea seeds (Miragreen) were lightly dusted with N-trichloromethylmercapto-4-cyclohexene-1,2-dicarboximide (captan) and planted in the infested soil, using three pots for each isolate, with 12 seeds per pot. The pots were kept for 5 weeks in a greenhouse with a regulated air temperature of approximately 22°. Disease in the tops, epicotyls, and roots of plants in each pot were separately rated using a scale similar to that of Lockwood and Ballard (5). Severe disease symptoms were rated as 3, intermediates as 2, and slight observable symptoms as 1. The separate ratings for the plants in each pot were totalled, and the average obtained for the three replicates of each isolate tested.

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[1]Journal Article No. 2798 from the Michigan Agricultural Experiment Station.
A portion of the M. S. Thesis of the senior author, Michigan State University.

RESULTS

F. solani f. pisi was readily isolated from surface-sterilized root tissues plated on water agar. T. basicola was rarely isolated by the agar plate method and microscopic examination of diseased root tissue showed chlamydospores of the fungus in plants from only one area (East Lansing). The number of root infections caused by this fungus was therefore based on isolation by the carrot disk technique. No colonies of A. euteiches were observed growing on the agar substrates. The number of A. euteiches infections recorded was based on microscopic identification of the characteristic thick-walled oospores of the fungus embedded in the root tissues.

Table 1 lists the number of diseased plants infected with F. solani f. pisi, A. euteiches, and T. basicola based on a total of eight plants collected from each field sampled. Pathogenic isolates of F. solani f. pisi were isolated from plants in all of the 19 fields sampled. A. euteiches was observed in plants from 14 of the 25 fields. T. basicola isolates were obtained only from diseased plants collected in three fields at Jackson and in one field at East Lansing. In the field at East Lansing, T. basicola appeared to be the principal pathogen based on symptoms, on the presence of large numbers of chlamydospores in the diseased tissues, and on isolations made of the fungus throughout the growing season.

Pathogenicity tests were made using 10 separate isolates of T. basicola obtained from plants collected in the Jackson and East Lansing areas. At the same time 35 of the F. solani f. pisi isolates were also tested for pathogenicity. The T. basicola isolates tested were all pathogenic on peas and had average disease indices from 1.7 to 5.5 (Table 2). In these tests the maximum rating for tops of plants was 1, showing that disease caused by some isolates was near the maximum for epicotyls and roots. All of the 35 isolates of F. solani f. pisi were pathogenic, and the roots and lower stems of the infected pea plants had disease symptoms similar in degree to those caused by T. basicola.

Peas infected with T. basicola root rot were characterized by having a black-brown necrosis of the cortex of the tap and lateral roots, and of the lower stem below the soil level (Fig. 1). Severe infection resulted in almost complete decay of the root system, wilting of the leaves, and stunting of the plants. Sometimes the stem below the soil line was girdled leaving the stele as the only connection between top and roots. The characteristic dark chlamydospores were abundant in the decayed tissues of severely diseased plants (Fig. 2). The external symptoms strongly resemble those caused by F. solani f. pisi which is also a cortical invader.

Table 1. Infection of roots of pea plants with three pathogenic fungi from Michigan pea fields.

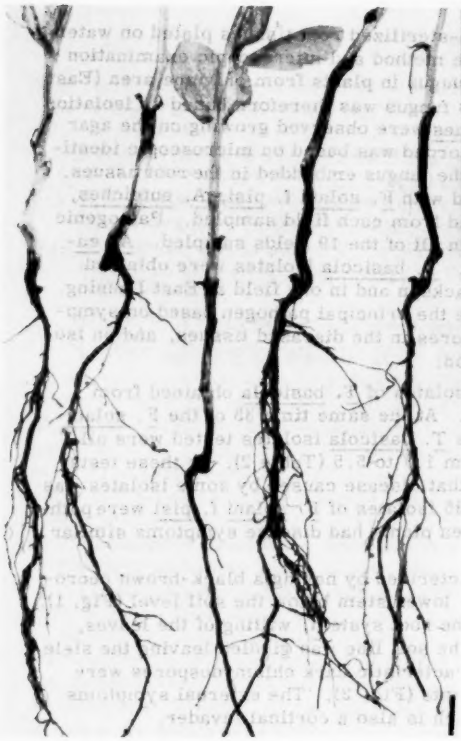
Area	No. of fields sampled	No. of plants infected with each fungus[a]		
		F. solani	A. euteiches	T. basicola
Caro	3	16	8	0
Montague	4	-	18	0
Saginaw	2	-	8	0
Croswell	6	28	6	0
Jackson	8	34	36	12
East Lansing	2	11	8	8
Total	25	89	84	20

[a] Eight plants were used for isolation, and eight were used for microscopic observations from each field. Data for F. solani f. pisi and T. basicola are based on isolations; those for A. euteiches are based on microscopic identification of oospores in diseased roots.

Table 2. Results of greenhouse pathogenicity tests of isolates of T. basicola.

Area	Isolate	Average disease index[a]
Jackson	21	5.0
	26	3.0
	27	2.5
	29	4.7
	33	1.7
E. Lansing	23	2.0
	25	5.5
	93	4.7
	94	4.3
	95	4.7

[a] Disease index was based on a scale of increasing severity from 0-9. Each figure is mean index of three pots, each with 12 plants.



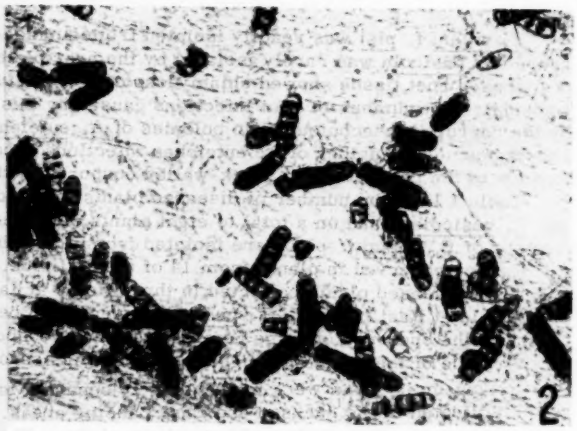


FIGURE 1. Thielaviopsis basicola root rot on Miragreen peas.

FIGURE 2. Chlamydospores of Thielaviopsis basicola in infected cortical tissues of pea roots.

DISCUSSION

F. solani f. pisi and A. euteiches are the most important pathogens in the pea root complex in Michigan. T. basicola was isolated from diseased root tissue of peas growing at East Lansing and at Jackson, but not at the four other locations. In one field at East Lansing the disease appeared to be due principally to this fungus. T. basicola is considered of potential importance in the pea root rot complex since isolates of this fungus were highly pathogenic in greenhouse tests, producing disease symptoms equal in severity to those caused by isolates of F. solani f. pisi.

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PARASITIC NEMATODES ON DIOSCOREA IN GUATEMALA

Eugenio Schieber[1]

In Guatemala there are several experimental plantations of dioscorea (tropical yam), also known in Guatemala as "alambrillo." This medicinal plant is grown in the country along the Pacific Coast for the production of cortisone precursors.

This report is based on the first survey made of nematodes that are a potential problem for the establishment of dioscorea plantations in the country.

In this survey, parasitic nematodes were found attacking three different species of dioscorea: Dioscorea floribunda, D. composita, and D. spiculiflora. Tubers, roots and soil samples were studied from collections made at three different locations in the Pacific Coast: Finca "Honduras" (Departamento Escuintla), Finca "El Naranjo" (Departamento Suchitepequez), and Finca "Las Delicias" (Departamento Retalhuleu).

Soil samples were processed in the laboratory using a modified Baermann funnel technique. For the identification of Meloidogyne species the technique described by Taylor, et al[2]. was used.

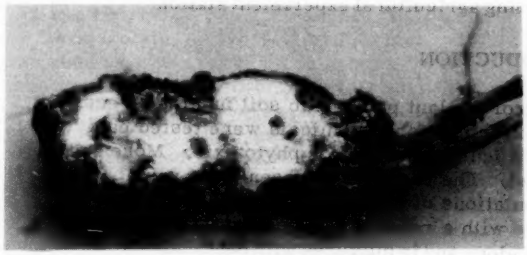

FIGURE 1. Tuber of Dioscorea composita showing nematode injury. (Photograph courtesy Dr. C. Bruhn).

The following parasitic nematodes were identified in this preliminary survey: Meloidogyne arenaria (Neal) Chitwood, M. incognita (Kofoid & White) Chitwood, and Heterodera sp.

Very high populations were found of M. arenaria at the three different locations. M. arenaria was found also on other hosts in the areas where dioscorea is grown, including Solanum aviculare and Caladium sp.

Symptoms on dioscorea are the rotting of tubers (Fig. 1), and poor growth of the roots with galls sometimes present. Aerial symptoms of seedlings attacked by nematodes include stunting, some foliar chlorosis, and necrosis. These symptoms are present in D. floribunda, D. composita, and D. spiculiflora.

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Acknowledgment is given to D. Lassmann K., and P. Escobar for helping with the laboratory work. To Mr. J. E. Shrum, Dr. C. Bruhn and Dr. B. A. Krukoff for furnishing plant and soil material.

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EFFECTIVENESS OF MIXTURES OF PYRIDINETHIOL DERIVATIVES AND PCNB (TERRACLOR) FOR CONTROL OF A COMPLEX OF SOIL FUNGI

G. L. Barnes[1] and R. S. Zerkel[2]

Summary

A controlled environment soil test is described for determining the effectiveness of fungicides for control of three economically important genera of soil fungi, singly or together. Preliminary evaluations of certain derivatives of 2-pyridinethiol, 1-oxide (Omadine) alone, and mixed with pentachloronitrobenzene (PCNB) (Terraclor), were completed during 1956 and 1957. In general, the order of activity of individual compounds against soil fungi is Pythium > Rhizoctonia > Fusarium. PCNB is highly toxic to Rhizoctonia but only slightly toxic to Pythium and Fusarium. Certain mixtures of individual Omadine derivatives with PCNB were more effective against a complex of the three fungi than a reference PCNB and captan mixture. Many of the mixtures were toxic to cotton and cucumber seedlings, but some of the more effective ones were only slightly toxic. Mixtures of cupric Omadine and PCNB and zinc Omadine and PCNB have been found to be effective in field tests at cooperating agricultural experiment stations.

INTRODUCTION

Treatment of soil with chemicals for control of plant pathogenic soil fungi has received considerable attention in recent years. Certain fumigatory chemicals were tested early but many have been found to be poor fungicides, difficult to handle, or phytotoxic. More recently, many nonfumigatory materials have been tested. The results have been quite variable depending on the material, the season, and local populations of soil fungi.

This report deals with the results obtained with a relatively new class of fungicides, 2-pyridinethiol, 1-oxide (Omadine) and derivatives, alone and in mixtures with pentachloronitrobenzene (PCNB) (Terraclor), for control of species of Rhizoctonia, Pythium, and Fusarium in soil.

Omadine and certain of its derivatives were first synthesized in the laboratories of the Squibb Division, Olin Mathieson Chemical Corporation, and the compounds were found to be highly active in vitro against certain bacteria and fungi of medical importance. Later, workers at the Ohio State University Research Foundation demonstrated that the compounds were also highly active against plant pathogenic fungi in laboratory tests and in greenhouse foliage and soil tests (1). Subsequently, activity against a wide spectrum of soil fungi was found in laboratory tests at the Univ. of California (5). Preliminary greenhouse and field tests were conducted by cooperators at several agricultural experiment stations. The zinc, copper, manganese, and disulfide derivatives were found effective for control of Pythium (14). High activity by the zinc, manganese, and disulfide derivatives was substantiated against Rhizoctonia (15). The manganese derivative was also found to be active against a species of Fusarium attacking carnation (8).

PCNB has been known to be very effective for the control of Rhizoctonia but it does not effectively control Pythium and Fusarium (4). Damping-off is frequently caused by a complex of soil-inhabiting fungi. Ideally, then, a soil fungicide should be formulated to be effective against all of the more important plant pathogenic soil fungi.

During 1956 and 1957 mixtures of individual Omadine derivatives and PCNB were tested for control of a fungal complex consisting of species of Pythium, Rhizoctonia, and Fusarium. Concurrently, mixtures of the manganese, zinc, or the disulfide derivative with disodium ethylene bisdithiocarbamate (nabam), and the zinc derivative with captan, were reported to have provided only equal or less control than the derivatives alone against the Rhizoctonia disease of cotton (15).

MATERIALS AND METHODS

Fungicides: All of the experimental fungicides were used as 10% dusts which were formulated by thoroughly ball-milling one part of technical fungicide(s) with nine parts of a diluent (eight parts pyrophyllite, Pyrax ABB, and one part of a synthetic calcium silicate, Micro Cell 805). A 10% formulation was used so that sufficient bulk would be present to aid in distributing small

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quantities of fungicides uniformly throughout relatively large volumes of soil. When mixtures of an Omadine compound and PCNB were tested, the following active ingredient ratios were used in the 10% dusts: 1:9, 3:7, 5:5, and 9:1. Rates, equivalent to 25, 50, and 100 pounds of active ingredient(s) per 3- or 4-inch acre, were usually used in the tests. The reference fungicide consisted of a 10% dust of PCNB and captan in a 6:4 ratio of active ingredients. The trade and chemical names of the test fungicides are as follows:

Trade name	Chemical name
Sodium Omadine	sodium 2-pyridinethiol, 1-oxide[a]
Zinc Omadine	zinc 2-pyridinethiol, 1-oxide[a]
Ferric Omadine	ferric 2-pyridinethiol, 1-oxide[a]
Cupric Omadine	cupric 2-pyridinethiol, 1-oxide[a]
Manganese Omadine	manganese 2-pyridinethiol, 1-oxide[a]
Disulfide Omadine	2, 2'-dithiodipyridine, 1,1'-dioxide[b]
Terraclor	pentachloronitrobenzene
Captan (common name)	N-trichloromethylmercapto-4-cyclohexene-1, 2-dicarboximide

[a]U. S. Patent No. 2,809,271 [b]U. S. Patent No. 2,742,476

Test Fungi and Hosts: Species of the three most common and destructive genera of plant pathogenic soil-inhabiting fungi were used: Rhizoctonia solani (Arndt Cotton Strain No. 2), Pythium sp. (Boyce Thompson Institute isolate), and Fusarium oxysporum f. cucumerinum n. f. (J. H. Owen isolate, University of Florida). Cotton (Gossypium hirsutum variety Coker 100 W) was used as indicator plant to assess control of Rhizoctonia and Pythium. Cucumber (Cucumis sativus variety Green Prolific) was used as the indicator plant for assessing control of Fusarium. Ten nontreated seeds of cotton (acid delinted) and/or cucumber were planted at a 1/2-inch depth in each container of soil in each test.

Fungus Inoculum Rates: All of the test fungi were cultured on steam-sterilized oat grains in 250-ml Erlenmeyer flasks for 10 to 14 days before use. Preliminary inoculum potential tests established that 2 grams of a culture of R. solani per half gallon of non-sterilized sandy loam soil was an optimum rate for test purposes because it allowed some survival of cotton seedlings. Higher rates produced unusually severe conditions which did not allow any survivors in the check containers. For both Pythium and Fusarium, approximately 20 grams of a culture per half gallon of test soil was an optimum rate.

For tests involving a complex of the three test fungi, a ratio of 1 gram of a Rhizoctonia culture and 4 grams each of cultures of Pythium and Fusarium per gallon of soil was an optimum inoculum mixture. The 1-4-4 ratio apparently permitted each fungus to become established in the soil. Evidence that each fungus contributed to damping-off was obtained by isolating the fungi from diseased host plants.

Soil: A natural non-sterilized sandy loam soil, apparently free of interfering plant pathogens and containing no added organic matter, was used in all of the tests. Soil having little organic matter is desirable for soil fungicide tests (13).

Soil and Air Temperature: Because 75° C is near the optimum for seedling infection of cotton by Rhizoctonia, Pythium, and Fusarium (2) and is also within the infection range of cucumber by F. oxysporum cucumerinum (7), this temperature was used in all of the tests.

Soil Moisture: The optimum water content of soils for moderate to severe Rhizoctonia damping-off is approximately 65% of field capacity, and that for Pythium damping-off is in the range of 85 to 95% of field capacity (3, 12). Therefore, sufficient water was added as needed to keep the soil moisture level above that actually required for good plant growth.

Illumination: Fluorescent tubes provided about 500 foot candles of light for the seedlings. Though the amount of light is not sufficient to support optimum growth over a long period, it was adequate for normal growth of cotton and cucumber seedlings during each 3-week test.

Fungicide Treatment of Soil: A Patterson-Kelley Twin Shell Blender equipped with a high-speed mixing bar was used for incorporating chemicals and fungus inoculum into soil. Particle distribution was found, by mixing powdered carbon into sand, to be uniform within 2 minutes. Three minutes was selected as a standard mixing time. During loading of the blender, direct contact was avoided between concentrated fungicides and inoculum by loading soil between additions of the amendments.

In the tests with individual Omadine compounds squat-type, half-gallon waxed food containers were used. In the test with mixtures of Omadine compounds and PCNB, 1-quart, waxed food containers were used. Three replications of the half-gallon containers and four replications of the quart containers were used.

Collection and Assessment of Data: After 1 week, pre-emergence damping-off data and early phytotoxicity information was obtained. At the end of 3 weeks, final data on fungicidal

efficacy were collected in the following categories: 1) % live plants in noninfested, nontreated soil; 2) % live plants in infested, nontreated soil; 3) % live plants in noninfested, treated soil. The following calculations were made in determining the efficacy of the fungicides:[3]

$$x = \% \text{ stand killed by fungi} = \frac{1) - 2)}{1)} \times 100$$

$$y = \% \text{ stand killed by fungi in treated soil} = \frac{1) - 3)}{1)} \times 100$$

$$\text{Control} = \% \text{ plants saved by treatment} = \frac{x - y}{x} \times 100$$

When injury occurred, two types were observed: pre-emergence killing of the seedlings and post-emergent killing or stunting. The degree of stunting was categorized as follows: none = height equal to plants in nontreated soil; slight = height at least 75% of height of plants in nontreated soil; moderate = height 50 to 75% of height of plants in nontreated soil; severe = height less than 50% of height of plants in nontreated soil.

The controlled environment soil fungicide test described above has recently been further modified and improved by Reinhart (11).

RESULTS AND CONCLUSIONS

Individual Omadine Compounds: Against Rhizoctonia, the cupric and disulfide derivatives provided about 60% control at 25 pounds/3-inch acre (Table 1). The cupric derivative was superior to the zinc derivative and gave 70 and 80% control at 50- and 100-pound rates, respectively, but caused a decrease in stand and moderate stunting. The disulfide derivative was very toxic at the 50- and 100-pound rates. PCNB, a specific for control of Rhizoctonia, provided 77 and 100% control at 58 and 115 pounds respectively, but caused a temporary slight stunting.

Against Pythium, the cupric and disulfide derivatives were more effective than the zinc derivative (Table 2). Excellent control (100%) of Pythium was obtained with the 50-pound rate of the disulfide derivative. Better control of Pythium than of Rhizoctonia was obtained with this derivative. However, the disulfide derivative was very toxic at the 100-pound rate. All three derivatives caused moderate stunting at the 50-pound rate.

Against Fusarium, the manganese derivative provided excellent control: 100% control at the 50- and 100-pound rates and 76% control at the 10-pound rate (Table 3). The 100-pound rate caused severe stunting of cucumbers. The disulfide derivative gave 74 and 72% control at the 10- and 20-pound rates, respectively, but was very toxic to cucumbers at higher rates. The zinc, ferric and cupric derivatives were ineffective for control of Fusarium.

Table 1. Control of Rhizoctonia damping-off of cotton by Omadine derivatives in soil.

Fungicide[a]	Rate (lb active/ 3-inch acre)	Infested series: % survival	Noninfested series: degree of stunting of survivors
Zinc Omadine	50	40	slight
	100	65	moderate
	200	73	severe
Cupric Omadine	25	63	slight
	50	70	moderate
	100	80	moderate
Disulfide Omadine	25	60[b]	moderate
	50	44[b]	moderate
	100	20[b]	moderate
PCNB	29	14	none
	58	77	slight
	115	100	slight

[a]Active ingredient of 10% dust.
[b]Both healthy and diseased plants killed.

Omadine and PCNB Mixtures: 1. Zinc Omadine and PCNB. The data indicated that the 1:9 and 5:5 ratios were the most effective for controlling the soil-fungus complex. However, the 5:5 ratio was more toxic (Table 4). The two effective ratios were slightly more effective than the reference fungicide mixture. The 50- and 100-pound/4-inch acre rates were more effective than the 10-pound rate. As the amount of zinc Omadine was increased in the ratios, disease control was decreased and phytotoxicity was slightly increased.

2. Cupric Omadine and PCNB. The data indicated that the 5:5 ratio was the most effective one and that it was superior to the reference fungicide mixture (Table 5). The 50- and 100-pound/4-inch acre rates of the 5:5

[3]This mathematical treatment of data was developed by Mr. David Shermer and Dr. Justin Reinhart, Olin Mathieson Chemical Corporation.

Table 2. Control of Pythium damping-off of cotton by Omadine derivatives in soil.

Fungicide[a]	Rate (lb active/ 3-inch acre)	Infested series: % survival	Noninfested series: degree of stunting of survivors
Zinc Omadine	50	23	moderate
	100	53	moderate
	200	100	moderate
Cupric Omadine	25	62	slight
	50	58	moderate
	100	72	moderate
Disulfide Omadine	25	69	moderate
	50	100	moderate
	100	49[b]	severe

[a]Active ingredient of 10% dust.
[b]Both healthy and diseased plants killed.

Table 3. Control of Fusarium damping-off of cucumbers by Omadine derivatives in soil.

Fungicide[a]	Rate (lb active/ 3-inch acre)	Infested series: % survival	Noninfested series: degree of stunting of survivors
Zinc Omadine	25	0	---
	50	0	---
	100	46	---
Cupric Omadine[b]	25	0	slight
	50	0	moderate
	100	0	moderate
Ferric Omadine	25	44	slight
	50	40	slight
	100	19[c]	moderate
Manganese Omadine	10	76	slight
	50	100	moderate
	100	100	severe
Disulfide Omadine	5	58	none
	10	74	none
	20	72	none
	25	0[c]	moderate
	100	0[c]	severe

[a]Active ingredient of 10% dust.
[b]Cotton (var. Deltapine 15) and cotton strain of Fusarium used.
[c]Both healthy and diseased plants killed.

ratio were more effective than the 10-pound rate. As the amount of copper Omadine in the ratios was increased, both fungitoxicity and phytotoxicity increased.

3. Disulfide Omadine and PCNB. The data indicated that the 1:9 and 5:5 ratios are very effective at the 50- and 100-pound/4-inch acre rates, but these rates caused moderate to severe stunting of both cotton and cucumber (Table 6).

4. Manganese Omadine and PCNB. The data indicated that all of the ratios and each dosage of each ratio provided control equal to or slightly better than that provided by the reference fungicide mixture (Table 7). As the amount of manganese Omadine was increased in the ratios, phytotoxicity was increased.

The stunting of seedlings of various crop plants growing in Omadine treated soil or in Omadine solutions or suspensions has been noted previously (1, 6). The stunting in the current tests is, perhaps, not as serious as the data might imply. First, a slight amount of stunting is attributable to the inoculum. This is evidenced by the slight stunting of survivors in infested, nontreated soil. Furthermore, unpublished data indicate that some of the stunting caused by either PCNB or the Omadine compounds is of a temporary nature from which plants eventually recover.

A number of conclusions can be made from the test data: 1. In general, the Omadine compounds alone were not quite so effective as PCNB for control of Rhizoctonia. The cupric derivative provided nearly equal control.

2. Of the Omadine compounds tested for control of Pythium, the cupric and disulfide derivatives provided the best control, but the disulfide derivative was quite phytotoxic.

3. In the case of Fusarium, both the manganese and disulfide derivatives provided good control. The manganese derivative gave 100% control at the 50- and 100-pound rates but was quite toxic to cucumbers. Good control (76%) was achieved with the 10-pound rate but slight stunting occurred. The disulfide derivative provided equivalent control at 10- and 20-pound rates. However, rates above 20 pounds were quite toxic to cucumbers.

4. When the ratio of an Omadine compound was increased in mixtures with PCNB, fungitoxicity and phytotoxicity increased. The same relationship was true for dosages.

5. Of all the mixtures tested, the zinc Omadine and PCNB combination in a 1:9 ratio was apparently the best mixture. The manganese Omadine and PCNB combination in a 5:5 ratio was second best. The third best combination was the cupric Omadine and PCNB mixture in a 5:5

Table 4. Control of a soil fungus complex by mixtures of zinc Omadine and PCNB.

Fungicide mixture (10% dust)	Active ingredient ratio	Rate (pounds active/4-inch acre)	Cotton: infested series % final stand	Cotton: infested series % control	Cotton: noninfested series degree of stunting of survivors	Cucumber: infested series % final stand	Cucumber: infested series % control	Cucumber: noninfested series degree of stunting of survivors
Zinc Omadine and PCNB	1:9	10	35	33	none	37	22	moderate
		50	78	88	none	80	100	moderate
		100	73	81	none	95	100	moderate
	5:5	10	18	10	none	40	28	slight
		50	50	52	none	70	85	moderate
		100	73	81	none	85	100	severe
	9:1	10	43	43	none	23	0	slight
		50	48	48	none	58	62	moderate
		100	68	74	slight	78	98	severe
PCNB and captan	6:4	10	8	0	none	55	56	---
		50	83	93	none	78	98	---
		100	65	71	none	63	72	---
Inoculated check	---	---	10	---	none	25	---	slight
Nontreated check	---	---	88	---	none	78	---	none

Table 5. Control of a soil fungus complex by mixtures of cupric Omadine and PCNB.

Fungicide mixture (10% dust)	Active ingredient ratio	Rate (pounds active/4-inch acre)	Cotton: infested series % final stand	Cotton: infested series % control	Cotton: noninfested series degree of stunting of survivors	Cucumber: infested series % final stand	Cucumber: infested series % control	Cucumber: noninfested series degree of stunting of survivors
Cupric Omadine and PCNB	1:9	10	23	19	slight	10	0	moderate
		50	55	45	moderate	0	0	---
		100	63	67	moderate	5	0	moderate
	5:5	10	43	43	moderate	30	22	moderate
		50	88	98	moderate	58	65	moderate
		100	85	93	moderate	73	89	severe
	9:1	10	85	93	slight	37	33	severe
		50	80	88	moderate	65	77	severe
		100	88	98	moderate	65	77	severe
PCNB and captan	6:4	10	37	35	slight	35	31	moderate
		50	70	76	slight	28	20	moderate
		100	80	88	moderate	43	43	moderate
Inoculated check	---	---	8	---	slight	15	---	slight
Nontreated check	---	---	90	---	none	80	---	none

Table 6. Control of a soil fungus complex by mixtures of disulfide Omadine and PCNB.

Fungicide mixture (10% dust)	Active ingredient ratio	Rate (pounds active/4-inch acre)	Cotton: infested series % final stand	Cotton: infested series % control	Cotton: noninfested series degree of stunting of survivors	Cucumber: infested series % final stand	Cucumber: infested series % control	Cucumber: noninfested series degree of stunting of survivors
Disulfide Omadine and PCNB	1:9	25	45	22	slight	43	52	none
		50	78	83	slight	30	35	slight
		100	58	46	slight	53	65	slight
	5:5	25	68	60	slight	28	32	slight
		50	65	59	slight	60	74	moderate
		100	43	19	moderate	80	100	severe
	9:1	25	40	13	slight	68	84	severe
		50	25	0	moderate	75	94	severe
		100	23	0	severe	70	87	severe
PCNB and captan	6:4	25	55	40	none	50	60	slight
		50	73	73	none	50	60	slight
		100	85	95	none	68	84	slight
Inoculated check	---	---	33	---	none	3	---	none
Nontreated check	---	---	88	---	none	80	---	none

Table 7. Control of a soil fungus complex by mixtures of manganese Omadine and PCNB.

Fungicide mixture (10% dust)	Active ingredient ratio	Rate (pounds active/4-inch acre)	Cotton: infested series % final stand	Cotton: infested series % control	Cotton: noninfested series degree of stunting of survivors	Cucumber: infested series % final stand	Cucumber: infested series % control	Cucumber: noninfested series degree of stunting of survivors
Manganese Omadine and PCNB	1:9	50	70	100	slight	8	0	slight
		100	65	95	slight	23	0	slight
	5:5	50	73	100	slight	48	37	moderate
		100	80	100	slight	70	70	moderate
	9:1	50	50	69	slight	70	70	slight
		100	70	100	moderate	78	82	severe
PCNB and captan	6:4	50	83	100	slight	35	18	slight
		100	88	100	slight	10	0	slight
Inoculated check	---	---	8	---	slight	23	---	slight
Nontreated check	---	---	68	---	none	90	---	none

ratio. The disulfide Omadine and PCNB mixture was the mixture most toxic to both cotton and cucumbers. The first two mixtures would probably perform the best under field conditions. With these mixtures, seeds of various plants could be planted immediately after soil treatment.

After this work was completed, a PCNB and cupric Omadine mixture and a zinc Omadine and PCNB mixture were reported to have provided excellent control of damping-off of cotton seedlings in field tests (9, 10). No injury was observed. These preliminary field test results suggest that further testing should be undertaken.

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USE OF WATER-EMULSIFIABLE ASPHALT WITH FUNGICIDES TO PROTECT CAMELLIA GRAFTS[1]

D. L. Gill[2]

Frequently camellia grafts fail, or the scion dies after growth begins, because of attack by the dieback fungus, Glomerella cingulata. Wounds made in preparing stock and scion for cleft grafts provide favorable entry for the fungus. Action of the fungus is further encouraged when grafts are covered with glass jars or other material to retain moisture. Grafts are heavily shaded until growth starts, at which time the covering may be removed gradually. Some growers do not remove the covering until scions have grown several inches. Heavy shading is often continued during the first growing season. To retain more moisture, some propagators cover the stump with soil, sand, or vermiculite before placing the outer covering.

Anzalone and Baxter (1) and Plakidas and Anzalone (4) obtained more successful grafts when they dipped trimmed scions in a suspension of captan or ferbam, 3 pounds to 100 gallons, and when they poured the fungicide over the completed grafts. These workers found a Bordeaux mixture dip injurious. Gill and McClurkin (3) reported that water-emulsifiable asphalt stimulated initial callus formation in wounds on camellia limbs. Forbes (2) used this asphalt to cover grafting wounds, and a number of propagators have followed this practice. Since heavy losses frequently follow grafting, I compared some of these methods and tested the value of adding fungicides to the water-emulsifiable asphalt used to cover graft wounds. Camellia japonica scions and understocks were used throughout.

MATERIALS AND METHODS

1958 Tests: In February 1958 single- (mostly lateral) bud scions of the camellia variety Ville de Nantes were grafted on understocks of the Blood of China variety. Most understocks were 1 1/2 inches in diameter at the stump, but a few were smaller. A few were transplanted from number 10 cans just before they were grafted. One to 12 scions were placed on each stock, commonly 4 to 8 on a stump. Eighteen stumps were grafted for each of eight randomized treatments as follows:

1. N-trichloromethylmercapto-4-cyclohexene-1,2-dicarboximide (captan 50%), 3 pounds to 100 gallons; scions dipped in suspension after trimming and inserted on stump, and suspension poured over graft and allowed to run into soil. No stump covering.
2. Ferric dimethyl dithiocarbamate (ferbam), 3 pounds to 100 gallons, as in 1.
3. Water-emulsifiable asphalt used to cover wound surfaces of stock and scion.
4. Water-emulsifiable asphalt plus ferbam, 3 pounds to 100 gallons, used as in 3.
5. Water-emulsifiable asphalt plus captan, 3 pounds to 100 gallons, used as in 3.
6. Stump covered with sharp sand after grafting.
7. Stump covered with vermiculite after grafting.
8. Stump with no cover or fungicide.

All grafts were enclosed with glass jars and shaded with burlap. There was little difference among treatments in the percentage of scions growing except that significantly fewer scions grew in the uncovered stump treatment and in the asphalt-ferbam treatment. These two treatments produced 15 and 14 growing plants, whereas the others produced 16 to 18 plants. Rechecking, however, showed that slightly inferior stocks were used in the asphalt-ferbam treatment.

1959 Tests: Scions and understocks were of the same varieties used in 1958. All grafts were sprayed with a conidial suspension of G. cingulata. In Group I the grafts were made February 17 and 18, the treatment applied at once, and the inoculation delayed until March 10. In Group II grafts were made February 23 and 24, the treatment applied immediately, and the inoculation made on the following day. Thirteen grafts were used for each treatment in Group I and 14 grafts for each treatment in Group II. Grafts were covered with polyethylene bags instead of glass jars. The treatments were as follows: 1 - 5, as listed in 1958; 6. water-emulsifiable asphalt plus N-trichloromethyl thiophthalimide (Phaltan), 3 pounds to 100 gallons, used to cover wound surfaces of stock and scion; 7. untreated control.

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[1]Cooperative investigations at Tifton, Georgia of the Crops Research Division, Agricultural Research Service, United States Department of Agriculture and the University of Georgia, College of Agriculture, Agricultural Experiment Station. Published with the approval of the Director as Journal Series No. 83.

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Table 1. Effects of treatments and inoculations with Glomerella cingulata on number of living scions and number of camellia grafts growing at end of season, 1959.

Treatment	Test 1				Test 2
	Plants grafted and inoculated Feb. 23-25		Plants grafted Feb. 17-18 and inoculated March 10		Plants grafted and inoculated July 24
	% scions growing	no. of 14 stocks with living scions	% scions growing	no. of 13 stocks with living scions	mean no. of 5 stocks with living scions
Captan 50% dip, 3 lb. to 100 gal.	15	6	59	10	1.0
Ferbam dip, 3 lb. to 100 gal.	15	6	58	11	0.8
Water-emulsifiable asphalt	30	8	57	12	2.0
Water-emulsifiable asphalt plus ferbam, 3 lb. to 100 gal.	36	11	63	11	3.0
Water-emulsifiable asphalt plus captan, 3 lb. to 100 gal.	58	12	45	10	3.8
Water-emulsifiable asphalt plus Phaltan, 3 lb. to 100 gal.	58	12	33	8	3.0
Control (inoculated)	2	1	36	8	0.0
Control (uninoculated)	-	-	-	-	3.8
L.S.D. 0.05	21	-	N.S.	-	1.3

Table 2. Effects of treatments and inoculations with Glomerella cingulata on number of living scions and number of camellia grafts growing at end of season, 1960. Grafts were made on February 29 and March 1.

Treatment	Inoculated		Uninoculated	
	mean no. of scions living of 4 per graft	total no. of 9 stocks with living scions	mean no. of scions living of 4 per graft	total no. of 9 stocks with living scions
Captan 50% dip, 3 lb. to 100 gal.	0.67	3	2.11	7
Ferbam dip, 3 lb. to 100 gal.	0.9	4	2.55	6
Water-emulsifiable asphalt	1.11	5	0.77	5
Water-emulsifiable asphalt plus ferbam, 3 lb. to 100 gal.	1.67	7	2.11	8
Water-emulsifiable asphalt plus captan, 3 lb. to 100 gal.	1.78	9	1.22	7
Water-emulsifiable asphalt plus thiram, 3 lb. to 100 gal.	2.0	8	1.89	7
Control	0.22	1	2.67	9
L.S.D. 0.05	0.94		1.14	

Data taken at the end of the growing season are shown in Table 1. When inoculations followed 1 day after grafting (Group II), more scions lived in the asphalt-fungicide treatments, and ferbam was inferior to the other two. The number of stocks with living scions differed little among the three asphalt-fungicide combinations. When inoculation was delayed (Group I) the asphalt-fungicide treatments showed no advantage over the others, but the asphalt-ferbam was slightly better than the other two asphalt-fungicide treatments.

In another 1959 test (Test 2, Table 1), Blood of China plants in number 10 cans were grafted July 24 with single- (lateral-) bud scions of Ville de Nantes. One scion was used on a stump. These grafts were kept in a shaded, pad-and-fan-cooled greenhouse. Treatments were the same as in February except for addition of an uninoculated control. All other grafts were inoculated after the treatments and before the polyethylene bags were applied. Twenty-five

grafts, arranged in five replications of five plants each, were made for each treatment. Table 1 shows the mean number of grafts growing for each treatment. The fungicides in water were less satisfactory than when mixed with asphalt. The results of asphalt-fungicide treatments were comparable to those of the uninoculated control.

1960 Test: The 1960 understocks were chiefly varieties Prince Eugene Napoleon, Adolphe Audusson, and C. M. Hovey. Four single- (lateral-) bud Ville de Nantes scions were grafted on each understock. Treatments were the same as in 1959 except for use of tetramethylthiuram disulfide (50% thiram) instead of Phaltan. Eighteen stocks were grafted for each of the seven treatments. After grafting and treating, nine grafts from each treatment were inoculated by spraying with a conidial suspension of G. cingulata. The other nine grafts were uninoculated. All grafts were covered with polyethylene bags and burlap. A screen giving 50% shade was placed over the area. Results are shown in Table 2. The water-emulsifiable asphalt plus the fungicides gave better results on the inoculated grafts. On the uninoculated grafts there was little difference due to treatment.

DISCUSSION AND CONCLUSION

The results show that when grafts were inoculated with Glomerella cingulata, covering the wounded surfaces with water-emulsifiable asphalt plus fungicides increased the graft takes as compared with no treatment or treatment with fungicides in water. When grafts were not inoculated the asphalt-fungicide combinations did not improve takes, nor were they injurious. Thus it seems that where poor results in grafting are anticipated because of G. cingulata infection, one of the asphalt-fungicide combinations should be used. Use of these materials is not a substitute for good graft management. Conditions favoring poor graft results are overshading, late aeration, lack of hardening before removing the cover, and overwatering. Overwatering is frequent when grafts are made on stocks growing in containers and when water is applied as if the top of the stock had not been removed.

Another possibility for securing better grafting results was suggested in the 1960 test. Here scion survival and production of living plants differed on the three rootstocks. On C. M. Hovey 44/152 scions lived (29%) and 24/38 rootstocks had living scions (63%). On Adolphe Audusson the survival of scions was 57/176 (32%), 25 of 44 rootstocks had living scions (57%). On Prince Eugene Napoleon the scion survival was 82/144 (57%), and 31/36 rootstocks (86%) had living scions. These results are the totals for both inoculated and uninoculated grafts.

When more is known of rootstock performance it may be preferable to select and propagate a rootstock for grafting purposes rather than to use any established plant with an undesirable top.

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DISTRIBUTION AND PATHOGENICITY OF STRAINS OF PSEUDOMONAS SOLANACEARUM FROM VIRGIN SOILS IN COSTA RICA[1]

Luis Sequeira[2] and C. W. Averre, III[3]

Summary

Although Pseudomonas solanacearum has been reported to occur on susceptible crops planted on freshly cleared land, the native reservoirs of infection have not been described. Surveys of more than 20,000 acres of virgin woodland in the Coto Valley of Costa Rica revealed extensive infection of three native species of Heliconia by the banana strain of P. solanacearum. The weed strain of this bacterium was also detected on Eupatorium odoratum. Although the incidence of Heliconia wilt was more severe in low-lying areas than at higher elevations, no correlations between soil type or drainage and the occurrence of the disease could be established. The isolates from diseased Heliconias were pathogenic to young banana plants, but wilt symptoms developed slowly giving a typical distortion syndrome, in contrast to the rapid wilt development usually obtained with isolates from infected bananas. The distortion syndrome predominates in bananas planted on recently cleared woodland, indicating a probable correlation between Heliconia wilt and banana wilt. The pathogenicity of Heliconia isolates increased after serial passage through banana, suggesting that this host exerts selective pressure for increased virulence within the endemic population of the bacterium.

In certain areas of the world bacterial wilt, caused by Pseudomonas solanacearum E. F. Sm., has been frequently reported on susceptible crops planted on recently cleared land. In Florida bacterial wilt was more severe on new castor bean (Ricinus communis) plantings on freshly cleared land than on land that had been in cultivation for several years (11). Similarly, Eddins (2) reported the almost complete loss of a potato (Solanum tuberosum) crop from a planting made on newly cleared land. The initial appearance of the disease on tobacco (Nicotiana tabacum) in North Carolina (4), on bananas (Musa cultivars) in Brazil and Trinidad (15, 13), and potatoes in South Africa (14) and Java (7) have also been noted. Although these reports suggest that P. solanacearum is a normal component of the microflora of many tropical and subtropical soils, Garner, et al. (3) could find no evidence that the disease was present in virgin soils in North Carolina and suggested that surface drainage from infested farms was responsible for the appearance of the disease in freshly cleared areas. Similarly, whereas Palm and Jochems (6) attributed the occurrence of tobacco wilt in virgin land to the presence of wild hosts, Smith and Godfrey (12) could find no correlation between the numbers of susceptible weed hosts in one season and the subsequent severity of wilt in tobacco. Thus, the possibility has been widely recognized that P. solanacearum exists in virgin soils, where it attacks wild susceptible hosts. However, direct proof of such native reservoirs of infection has not been presented and it is apparent that contamination through drainage water, planting stock and other sources has complicated the picture in many instances.

The rapid appearance and spread of bacterial wilt of bananas (Musa Gros Michel) in newly planted areas in the Coto Valley of Costa Rica (8) suggested in most instances that the bacterium was present in virgin soils. This hypothesis was strengthened by the findings of Buddenhagen (1) who reported a wilt disease of Heliconia latispatha, a musaceous weed growing in abandoned banana farms in Coto. This disease was caused by a strain of P. solanacearum having the features of colony morphology associated with the B or banana strain. Because several species of Heliconia are widespread members of the underbrush in the forests of the Coto Valley and bananas are commonly planted on sites where Heliconias normally grow, the latter often remaining as tenacious weeds, it seemed desirable to survey virgin lands in an effort to

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Grateful acknowledgment is expressed to Professor Arthur Kelman for many helpful suggestions and a critical review of the manuscript and to Mr. Luis Gonzalez for technical assistance.

establish whether bacterial wilt was present in these areas. Information from such surveys would be of considerable practical importance in the selection of farm sites in any program for expansion of the banana industry in Costa Rica. Preliminary accounts of this work have been presented (9, 10).

Distribution of P. solanacearum in Virgin Woodland Areas: The planting of bananas in extensive areas of recently cleared virgin woodland in the Coto Valley during the early part of 1959 provided an opportunity to study the natural incidence of bacterial wilt. Within 3 months after planting, several cases of a disease resembling bacterial wilt of bananas were detected. Although the outward symptoms of the affected plants did not agree with those normally associated with the disease, laboratory isolations proved that the organism involved was P. solanacearum. An examination of the weeds growing in the immediate vicinity of the diseased banana plants revealed several plants of Heliconia latispatha with a definite browning and shriveling of the center leaves, which was associated with a soft, watery rot of the root system. In some cases, the outward appearance of the plants was quite normal, but an examination of the stem and root systems often showed a brown discoloration of the stelar region, where bacteria oozed out in distinct droplets within a few minutes after the surface was cut. Vascular discoloration in the pseudostem tissue was absent or negligible. A large number of isolations made from the pseudostem, rhizome, and roots of diseased Heliconias yielded P. solanacearum in all instances.

In the Coto Valley, P. solanacearum exists in the form of two well defined strains, the "B" or banana strains and the "T" or weed strain (1, 8). These strains can be distinguished on the basis of colony morphology, formation of pigment on a tyrosine medium, and host range. The growth of most isolates from Heliconia on a tetrazolium medium (5) appeared to be typical of the B strain. Several isolates, however, attained a pink coloration on this medium within 48 hours and presented many of the morphological features that are usually associated with the strain (T) that attacks solanaceous hosts. When grown on a medium containing 1-tyrosine (.1%), these atypical Heliconia isolates did not produce the brown pigment characteristic of the T strain and therefore this group of isolates was tentatively designated as the "R" strain.

To determine whether the disease occurred throughout areas where contamination from existing cultivations could not have occurred, laborers trained to recognize the disease in the field were organized in crews to survey approximately 20,000 acres of woodland. In areas where roads were available, inspections were made along lines spaced 75 m apart. Where access was not possible through roads, lines were cut at 900-m intervals and inspections carried along transects made between lines at approximately 90-m intervals. The areas surveyed included the Coto North and Coto South banana development projects, located to the northwest and southeast of the town of Coto, Costa Rica. Each project was divided into 25-acre sections to facilitate recording of the approximate location of the areas sampled. Samples from rhizomes of all Heliconia clumps showing symptoms of bacterial wilt were collected and brought to the laboratory. A preliminary screening was made by making a fresh cut across the rhizome and checking visually for discoloration and rot of the stelar region. Those samples suspected of infection were further screened by placing a thin sliver of discolored rhizome tissue in a test tube containing sterile distilled water. Within a few minutes bacteria exuded from infected tissue caused visible turbidity of the water and this bacterial suspension was then streaked on a tetrazolium medium. After incubation for 48 hours at 30° C the plates were examined for the presence of colonies of P. solanacearum.

The surveys indicated that Heliconia wilt is present at scattered locations throughout the Coto Valley. The following species of Heliconia were attacked by P. solanacearum under natural conditions: H. latispatha, H. acuminata, and H. imbricata. Typical symptoms of the disease on H. imbricata are shown in Figure 1.

The disease appeared only at scattered locations even in areas where solid stands of Heliconia existed, indicating that lateral spread under natural conditions is a relatively slow process. No instances were found, even in the most heavily infested areas, where the disease was obviously spreading throughout the solid mass of Heliconias that constitute the main component of the underbrush. In contrast, however, in areas felled several years prior to planting and which had had repeated chopping of the underbrush, particularly along roadways and drainage canals, cases of Heliconia wilt were found in large numbers; this extensive invasion is indicative of the potential extent to which the disease can be spread when mechanical transmission through infested knives and other tools is involved (8).

Maps showing the approximate location of infested sections are shown in Figures 2 and 3. A section was marked positive if one or more samples from the 25-acre plot yielded P. solanacearum upon isolation. When soil and contour maps were superimposed on the survey maps,

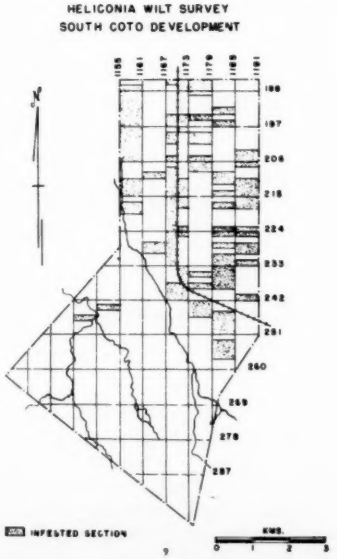
FIGURE 1. Mature plant of Heliconia imbricata naturally infected with Pseudomonas solanacearum in virgin woodland, Coto, Costa Rica. Note wilted center leaves.

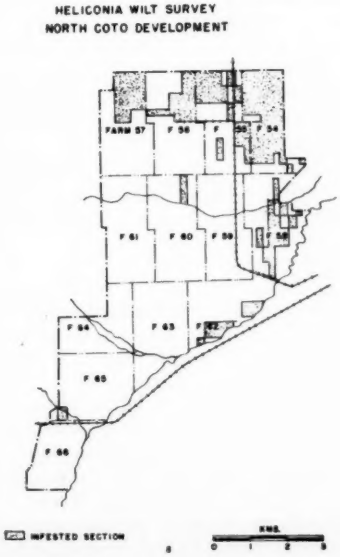
no particular correlations between soil types or drainage and the occurrence of the disease could be established. In most instances, however, incidence of the disease was more severe in low-lying areas than at the higher contours, suggesting the possibility of spread of the causal organism through flood waters.

During the course of the surveys for Heliconia wilt, the T or weed strain of Pseudomonas solanacearum was often isolated from wilted Eupatorium odoratum plants present in virgin woodland. Thus, the T strain of this bacterium is also indigenous to the Coto Valley and is often present in the same areas where the B strain is prevalent.

Pathogenicity of P. solanacearum Isolates from Heliconia: Inoculations were made with water suspensions prepared from colonies of the B-strains of P. solanacearum obtained from banana and Heliconia and the R-strain from Heliconia. These suspensions were standardized turbidimetrically and injected with a hypodermic syringe into the base of the pseudostem of 1-month-old banana (var. Gros Michel) plants growing in sterilized soil. The results are shown in Table 1 and they indicate clearly that the B-strain isolates from Heliconia are pathogenic to banana, but cause only a slow wilt syndrome in contrast to the rather dramatic quick wilt obtained with the normal B-strain isolates from banana. The isolates from Heliconia produced symptoms consisting mainly of folding of one or two of the center leaves and distorted development of the unfolding new leaf. These symptoms were associated with extensive vascular discoloration in the youngest leaves and rhizome. Collapse of the leaves occurred slowly, but within 3 weeks after inoculation the plants presented extensive twisting and splitting of the pseudostem, and the leaf sheaths often pulled apart (Fig. 4).

The slow wilt symptoms obtained by inoculation with these isolates were very similar to those described by Buddenhagen (1) as characteristic of the "distortion" syndrome, a type of bacterial wilt rarely seen in older banana plantings. The results of inoculations carried out with the R-strain isolate from Heliconia showed that this strain has very limited pathogenicity towards bananas, as the bacterium grew poorly within the host and produced only slight dis-





FIGURES 2 and 3. Maps of the South Coto and North Coto developments showing the position of sections infested with Pseudomonas solanacearum. Each section approximately 25 acres.

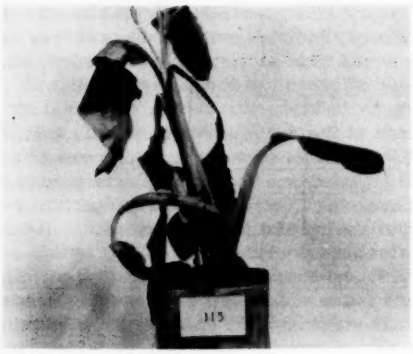


FIGURE 4. Young Gros Michel banana plant showing characteristic "distortion" symptoms following inoculation with a Heliconia isolate of Pseudomonas solanacearum. Photographed 1 month after inoculation.

Table 1. Wilt indexes[a] of banana plants inoculated with various isolates of P. solanacearum.

Days after inoculation	"B" strain		"R" strain
	Heliconia	banana	Heliconia
8	24.9	62.7	11.3
15	46.3	85.9	17.9
22	61.3	92.6	10.6
29	66.3	97.5	9.3

[a]Wilt indexes based on wilt ratings 0-6 converted to percentage.

Table 2. Cross-inoculation tests with various isolates of P. solanacearum.

Isolate number	Source	Strain	Pathogenicity rating					
			banana	Heliconia	tomato	S. nigrum	tobacco	M. balbisiana
115	Heliconia	B	high	high	low	low	low	high
132	Heliconia	B	high	high	low	low	--	--
118	Heliconia	R	low	high	low	low	low	low
117	Banana	B	high	high	low	low	low	high
111	Physalis	T	low	low	high	--	--	--
123	Eupatorium	T	low	low	high	high	high	low

Table 3. Average wilt indexes of four isolates of P. solanacearum serially passed in Gros Michel bananas.

Isolate number	Strain	Passage number	Wilt index (11 days)	
			original	serially passed
164	B	7	31.7	51.5**
118	R	5	17.0	13.7
167	B	5	30.0	60.8**
123	T	5	15.8	13.7

** Differences between the original and serially passed isolates significant at P:0.01.

coloration of the vascular bundles in discrete pockets.

The pathogenicity of the strains of P. solanacearum from virgin areas was determined by cross inoculation trials on solanaceous and musaceous hosts. Plants of banana (Musa Gros Michel), Heliconia latispatha, tomato (Lycopersicon esculentum local var. California), tobacco (Nicotiana tabacum var. Bottom Special), Musa balbisiana and Solanum nigrum growing in 6-inch pots were inoculated with standardized bacterial suspensions from 48-hour cultures of the various strains of P. solanacearum. In the case of banana, Musa balbisiana, and Heliconia latispatha, 1/2 ml per plant of the bacterial suspension was injected at the base of the pseudostem. Other host plants were inoculated by the standard leaf axil puncture technique (17).

Pathogenicity ratings were made within 4 days after inoculation in the case of tomatoes; other host plants were rated within 8 to 10 days after inoculation. A rating of "low" pathogenicity was given to isolates inducing symptoms below a disease index of 30%; "high" pathogenicity to isolates inducing symptoms above a disease index of 60%. A greatly simplified summary of the results obtained is shown in Table 2.

The results indicate that all Heliconia isolates have very low pathogenicity toward solanaceous hosts and, conversely, that Heliconia latispatha is not susceptible to the T-strain isolates from virgin woodland. Also, the B and R strains from Heliconia can be readily differentiated on the basis of their pathogenicity toward banana or Musa balbisiana. Thus, the B-strain isolates will attack all musaceous hosts but the R-strain isolates are known to attack only species of Heliconia.

Influence of Serial Passage on the Virulence of Heliconia Isolates: In virgin areas that were planted to bananas after the Heliconia wilt survey had been completed, banana wilt appeared almost exclusively in those sections where the survey had indicated a high incidence of Heliconia wilt. The distortion syndrome was prevalent on diseased bananas in these areas and these characteristic symptoms suggested a high correlation between Heliconia wilt and banana wilt. Should banana wilt follow in these newly planted areas what we assume to be the typical pattern of older banana farms, the distortion syndrome will be replaced in time by the more virulent fast wilt type of disease. In the more recently planted farms, for instance, the distortion type predominates in a ratio of 200-300 cases to one fast wilt case, but in farms planted 5 to 10 years previously, distortion cases are rarely seen. This change from the distortion to the fast wilt syndrome probably reflects a high rate of spread of the fast wilt strains from a few original foci of infection, leading to their eventual predominance in banana plantations. However, inoculations with more than 80 isolates from diseased Heliconia plants collected from many locations in the Coto Valley invariably yielded the distortion syndrome on bananas. Possibly, therefore, the fast wilt strains could also appear as a result of passage of the distortion strains through the banana host. By a process of mutation and/or selection, the original distortion strain may be replaced by more virulent cells. A similar mechanism has been proposed by Wellhausen (16) to explain changes in levels of virulence in Xanthomonas stewartii, the causal agent of Stewart's wilt of corn. To test this possibility, four different isolates of P. solanacearum: a Heliconia isolate (B strain), a "distortion" banana isolate (B strain), an atypical Heliconia isolate (R strain), and an isolate from Eupatorium odoratum (T strain), were serially passed on Gros Michel bananas. Inoculations employed the pseudostem injection technique and reisolations were made on a tetrazolium medium. All isolates were serially passed at weekly intervals at least five times in the banana plants. At the conclusion of the passages, the virulences of the serially-passed isolates and those of the original isolates were compared. Inoculations with standardized bacterial suspensions were made on young banana plants growing in sterilized soil. Disease readings were taken 11 days after inoculation on a 0-6 scale and converted to percentage. Five plants per treatment were inoculated and the experimental design was a randomized complete block with four replications of each treatment. The results are shown in Table 3.

The data show clearly that the distortion isolates from Heliconia and banana were made more virulent by serial passage through the banana host. On the other hand, serial passage of the atypical R-strain from Heliconia and the T-strain from Eupatorium had no influence on their virulence to banana. The results of this test suggest, therefore, that the planting of bananas in virgin soils in the Coto Valley may exert selective pressure on the indigenous B strains of the bacterium, thus allowing the more virulent cells to become predominant.

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CONTROL OF APPLE BLOTCH WITH FUNGICIDES

F. Ben Struble and Lou S. Morrison[1]

Summary

In the control of Phyllosticta solitaria, causal organism of apple blotch, it was demonstrated through trials in which various fungicide applications were omitted that the major portion of blotch infection in Oklahoma occurred 2 to 4 weeks after petal fall. Blotch was satisfactorily controlled with two or three fungicide applications at 2-week intervals beginning at petal fall.

Of the organic fungicides tested, ferbam, zineb, captan, thiram, and the Mn salt of pyridinethione, all provided good blotch control.

INTRODUCTION

Blotch, caused by Phyllosticta solitaria Ell. & Ev., is a common disease of apples in Oklahoma. In years with frequent spring rains, 50% or more of the fruits in many orchards may be infected. While Oklahoma is not a major apple-producing area, there are many small orchards that produce for local consumption.

Earlier work (3, 4, 5, 7, 10) on control of blotch was concerned mainly with the timing necessary for fungicide applications and the relative merits of Bordeaux mixture and liquid lime-sulfur. Scott and Rorer (10) gave the time of first infection as 4 to 5 weeks after petal fall. Most of the other earlier workers seem to be in general agreement on this timing. Later work by Gardner, et al. (3) points out that while infection generally does not begin before 2 weeks after petal fall, it may start sooner. Bordeaux mixture generally has been considered to provide control superior to that obtained with lime-sulfur. Generally, fruit injury following the use of Bordeaux has resulted in the recommendation that lime-sulfur be substituted in the earlier sprays.

Since the earlier work, trials with more modern fungicides against blotch have included fixed coppers (6), ferbam (1, 2, 9), the copper derivative of 8-quinolinol and tris (2-hydroxyethyl) (phenylmercuri) ammonium lactate (8). There appears to be no published record of the effectiveness of newer fungicides for blotch control. The present work was an attempt to evaluate several newer fungicides for blotch control and to determine the timing necessary for effective fungicide applications under Oklahoma conditions.

MATERIALS AND METHODS

This work was started in 1952 and was continued through 1958. All tests were conducted near Keystone, Oklahoma, in either the orchard of J. R. Fleming or of E. W. Pogue.

In all tests, single-tree replicates in randomized blocks were used. The number of replicates varied from four to five depending upon the season and availability of suitable trees. The apple varieties used were Henry Clay, an early variety maturing mid- to late June, and Golden Delicious, a later variety maturing late August to early September.

All spray applications were made with a hand gun using conventional hydraulic equipment. Spray applications were made at approximately 2-week intervals. Control trees received only insecticide. During the period of these tests either lead arsenate or 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane (DDT) was used for codling moth control. Usually one to two applications of a miticide were also necessary. Miticides used during the test period included dicyclohexylamine salt of 2-cyclohexyl-4,6-dinitrophenol (DN-111), 2-(p-tert-butylphenoxy)-isopropyl 2'-chloroethyl sulfite (Aramite), and S-(1,2-bis(ethoxycarbonyl)ethyl) O,O-dimethyl phosphorodithioate (malathion).

In each of 4 years, omission trials were run to determine the timing necessary for fungicide applications in apple blotch control. In these tests a standard fungicide was used in what was considered a full-season program beginning at petal fall. Some omission trials were run so that the standard fungicide was applied starting 2, 3, or 4 weeks after petal fall. Other omission trials were run so that all plots received fungicide beginning at petal fall and then the first, second, or third cover spray was omitted. All trials included an unsprayed control for comparison.

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Table 1. Control of blotch by fungicides in each of several years on the apple variety Henry Clay.

Fungicide[a] (rate/100 gallons)	% fruits with lesions	Year	Avg no. lesions/ infected fruit
		1953	
Sulforon, wettable sulfur, 6 lb.	23		2.7
Captan, 50% (Orthocide 50W) 2 lb.	6		1.5
Ferbam, 76% (Fermate) 2 lb.	0		
Bordeaux mixture[b] 2-4-100	13		2.7
None	21		8.3
		1954	
Sulforon	51		6.9
Captan	8		1.4
Bordeaux mixture[b]	8		2.0
Glyodin, 1 qt.	38		4.3
None	48		8.1
		1956	
Captan	4		1.3
Thiram, 65% (Thylate) 1.5 lb.	3		1.1
Zineb, 65% (Dithane Z-78) 1.5 lb.	1.4		1.0
Omadine, pyridinethione Mn salt, 50% 1.5 lb.	5		1.5
None	27		3.4
		1958	
Captan	4		1.5
Thiram	0		
Zineb (Dithane Z-78)	0.4		1
Zineb, 56% (Parzate) 1.5 lb.	0		
None	76.6		8.6

[a]Composition of fungicides and rates at which used are not repeated after the first listing of a material.

Captan = N-trichloromethylmercapto-4-cyclohexene-1,2-dicarboximide; ferbam = ferric dimethyl dithiocarbamate; glyodin = 2-heptadecyl glyoxalidine acetate; thiram = tetramethylthiuram disulfide; zineb = zinc ethylene bisdithiocarbamate; Omadine = 2-pyridinethione 1-oxide manganese salt.

[b]Sulforon used in petal fall application.

In addition to the omission trials, trials with several different fungicides applied in a full-season program beginning at petal fall were run in each year from 1952 through 1958. Fungicides included in these trials are listed in Table 1.

RESULTS AND CONCLUSIONS

Because the same fungicide was not used as a standard in all years, and because different omissions were used some years, the results on omission trials are difficult to summarize and present briefly. However, from these data it is possible to make certain definite conclusions. In most years, fungicide applications begun 2 weeks after petal fall were as effective in blotch control as those started at petal fall. A single petal fall application did not provide adequate blotch control. While in some years there was evidence of earlier infection, in most years the major part of blotch infection occurred in the period from 2 to 4 weeks after petal fall. Two or three fungicide applications beginning at petal fall with 2-week intervals between applications were generally as effective as four or more applications. In some years there was evidence of new infection on Golden Delicious 2 months after petal fall. Disease incidence and severity were directly correlated with rainfall.

In Table 1 representative data from several years are presented to show the relative effectiveness of several fungicides in blotch control. While the data are for the variety Henry Clay, similar results were obtained with those fungicides tested also on Golden Delicious. On Henry Clay, three spray applications were made each year beginning at petal fall except in 1954 when a fourth cover spray was added.

From these data it will be noted that all of the newer organic fungicides tested, with the

exception of glyodin, gave satisfactory control of blotch. Zineb is the presently recommended fungicide for blotch control in Oklahoma.

In 1957 no fungicide gave satisfactory blotch control. In this year 95% of the unsprayed fruits of the variety Henry Clay had blotch with an average of 49 lesions per infected fruit. Even with the best treatment, Parzate, 65% of the fruits had blotch with an average of five lesions per infected fruit. The high incidence of blotch was attributed to excessive rainfall. At times it was not possible to spray at the proper time because of rain or mud. During May, rain was recorded on each of 18 days for a total of 13.93 inches. In June rain fell on each of 10 of the first 20 days for a total of 5.71 inches. Henry Clay fruits were harvested June 20.

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THE NORTH AMERICAN 1961 SET OF SUPPLEMENTAL DIFFERENTIAL WHEAT VARIETIES FOR LEAF RUST RACE IDENTIFICATION

A Committee of North American Wheat Leaf Rust Research Workers[1]

A method of race identification and nomenclature for wheat leaf rust (Puccinia recondita Rob. ex. Desm.) involving the use of supplemental differentials was proposed in 1959[2]. The first group of such differentials was to be chosen from a group of 16 test varieties and selections suggested at that time by various workers. Rather extensive testing of this group of varieties has shown that at least four will differentiate cultures of wheat leaf rust which carry genes for virulence important in the North American area but not differentiated on the eight standard differentials. The committee agreed that these four varieties (Table 1) would constitute the NA61 set of supplemental leaf rust differentials. Races identified on this set of differentials will carry the designation "NA61-" in accordance with the system of nomenclature proposed in 1959.

Table 1. The NA61 set of supplemental differential wheat varieties for leaf rust race identification.

Name	C. I. no.
Lee	12488
Westar	12110
Sinvalocho	12595
Waban	12992

On the basis of their behavior in the testing program, the remaining 12 1959 test varieties were grouped as follows:

1. Universally Resistant: The following varieties were resistant to all cultures used for testing: Agrus, C. I. 13228; Transfer, C. I. 13483; Klein Lucero, D. I. V. 8386; and Aniversario, C. I. 12578. It is proposed that these varieties be used for the detection of new genes conditioning virulence.
2. Test Varieties: The following varieties seemed to have potential use as supplemental differentials but further testing was suggested: Exchange, C. I. 12635; Rio Negro, C. I. 12469; Wesel, C. I. 13090; Newsar, C. I. 12530; and Wardal, C. I. 13372. Three new varieties have been suggested for this group as follows: South Africa 43 (SA43), C. I. 13658; Dular (Dlr), C. I. 13373; and Wanken (Wk), C. I. 13659.
3. Dropped: Three varieties had little potential as differentials and were dropped from further testing as follows: Colotana, C. I. 13556; Klein Titan, D. I. V. 396; and (Honor[2] - Rosen Rye x Yorkwin) x Cornell 595, C. I. 13078. (The last selection is apparently cytologically unstable[3].)

When the NA61 set of supplemental differential wheat varieties is used for leaf rust race identification, the designation "NA61-" should always be applied. Added clarity and historical continuity will result by giving, when known, the race designation determined on the standard differential varieties; for example, "9-NA61-5."

A key using the NA61 set of supplemental differential varieties was prepared in which only two categories of reaction classes (resistant and susceptible) were recorded. Although various degrees of resistance and susceptibility were used in recording varietal behavior at the time readings were made, these were combined into only the two reaction classes. Infection types 0, 0;, 1, 2-, and 2+ were placed in the resistant class, whereas types 2++, X[4], Y[5], 3,

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[2]A Committee of North American Wheat Leaf Rust Research Workers. 1959. A proposed modification of the system of wheat leaf rust race identification and nomenclature. Plant Disease Reptr. 43: 613-615.

[3]Sebesta, E. E. Unpublished Ph. D. Thesis. Cornell Univ. 1959.

[4]X = Mesothetic reaction.

[5]Y = Mesothetic type reaction but with all resistant type pustules toward the base of the leaf.

Table 2. Reaction of the wheat varieties making up the NA61 set of supplemental leaf rust differentials to 15 NA61 races of Puccinia recondita.

NA61 race number	Reaction of differential variety			
	Lee (C. I. 12488)	Westar (C. I. 12110)	Sinvalocho (C. I. 12595)	Waban (C. I. 12992)
1	R	R	R	R
2	R	R	R	S
3	R	R	S	R
4	R	R	S	S
5	R	S	R	R
6	R	S	R	S
7	R	S	S	R
8	R	S	S	S
9	S	R	R	R
10	S	R	S	R
11	S	R	S	S
12	S	S	R	R
13	S	S	R	S
14	S	S	S	R
15	S	S	S	S

Table 3. Analytical key for leaf rust (Puccinia recondita) races identified by the reaction of the NA61 set of supplemental differential varieties.

	NA61 race no.
Lee resistant	
Westar resistant	
Sinvalocho resistant	
Waban resistant	1
Waban susceptible	2
Sinvalocho susceptible	
Waban resistant	3
Waban susceptible	4
Westar susceptible	
Sinvalocho resistant	
Waban resistant	5
Waban susceptible	6
Sinvalocho susceptible	
Waban resistant	7
Waban susceptible	8
Lee susceptible	
Westar resistant	
Sinvalocho resistant	
Waban resistant	9
Sinvalocho susceptible	
Waban resistant	10
Waban susceptible	11
Westar susceptible	
Sinvalocho resistant	
Waban resistant	12
Waban susceptible	13
Sinvalocho susceptible	
Waban resistant	14
Waban susceptible	15

and 4 were placed in the susceptible class; thus, the data are recorded in Table 2 as R (resistant) and S (susceptible) rather than in the form of infection types.

The use of four differential varieties and two reaction classes allows only 16 possible races. Fifteen of the possible races were found in studies with the NA61 set of supplemental differentials. These 15 races were assigned numbers[6] in compliance with the system previously proposed, and the reactions of the four supplemental differentials to the 15 races are given in Table 2.

The data shown in Table 2 were used to prepare the dichotomous key (Table 3). After careful consideration, it seemed best to make the first division by use of the variety Lee, C. I. 12488, and the other varieties gave the best separations if used in the order shown. However, good separations probably could have been obtained by using a small number of differentials in almost any order.

[6]C. O. Johnston has made assignment of the NA61 race numbers.

RELATIVE PREVALENCE OF NA61 RACES OF PUCCINIA RECONDITA IN 1960 IN KANSAS AND OKLAHOMA

C. O. Johnston and H. C. Young, Jr.[1]

Summary

A total of 14 NA61 races was identified by the use of the North American 1961 set of supplemental differentials in collections of leaf rust of wheat (Puccinia recondita Rob. ex. Desm.) studies in Kansas and Oklahoma in 1960. Some NA61 races were found in only one standard race, whereas others were found in several standard races. Four NA61 races (NA61-14, NA61-5, NA61-12, and NA61-3) constituted approximately 80% of the 250 isolates tested.

INTRODUCTION

A rather large number of isolates of wheat leaf rust (Puccinia recondita Rob. ex. Desm.) were used in Kansas and Oklahoma to study the 16 test varieties suggested as possible supplemental differentials by the Committee of North American Wheat Leaf Rust Research Workers[2]. As a result of these studies and similar one in other States and Canada, four varieties were chosen by the Committee for use as supplemental differentials in the North American area[3]. A review of the reaction of these four varieties to the various isolates used in the Kansas and Oklahoma tests during 1960 served as a basis for determining the prevalence of the various races identified on the NA61 set of supplemental differentials. The methods of handling these rust cultures are in common use and need no further elucidation.

RESULTS

It was expected that the use of supplemental differentials would not only determine additional races but that more than one NA61 race would be found in the same standard physiologic race. This was found to be true, and in many cases the same NA61 race was found in several different standard physiologic races. A total of 250 cultures was used in these studies, and the NA61 races found in certain standard physiologic races in 1960 are shown in Table 1. In most cases the same NA61 race was found in several of the standard physiologic races. For example, NA61-5 was found in 8 different standard races, NA61-7 in 7, NA61-12 in 6, and NA61-14 in 11. The data also show that certain NA61 races were very abundant in certain standard races. For example: In standard race 2, NA61-12 was most abundant; in standard race 5, NA61-14; in

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[3]A Committee of North American Wheat Leaf Rust Research Workers. 1961. The North American 1961 set of supplemental differential wheat varieties for leaf rust race identification. Plant Disease Reptr. 45: 444-446.

Table 1. Number of isolates of NA61 races of Puccinia recondita found in certain standard physiologic races in 1960 in Kansas and Oklahoma.

Standard race number	Number of isolates of indicated NA61 races														Total isolates of standard race
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
1	1														1
2	1		7		3		6		1			16		9	43
5			7	1										10	18
6			1											9	10
9	3				11									1	15
10					2										2
11	1											2		1	4
15	1	1	24		4		5		1	1		20		32	89
19												2			2
20					3	1						1	1		6
21				1											1
28							1							4	5
31					19		1					2			22
32				1											1
35				2											2
52					1		1							1	3
54				2											2
58							1		1					1	3
77			1	2				2							5
105					1		1							2	4
122				6				2			1				9
126			1												1
130														1	1
131	1														1
Total isolates of NA61 races	8	1	41	15	44	1	16	4	3	1	1	43	1	71	250

standard race 9, NA61-5; in standard race 15, NA61-3, NA61-12, and NA61-14; and in standard race 31, NA61-5.

Races NA61-14, NA61-5, NA61-12, and NA61-3 were identified most frequently, and all occurred in several different standard races. These four NA61 races constituted approximately 80% of the isolates studied and have only one character in common. Waban is resistant to all four. On the other hand, five NA61 races were encountered only once each (NA61-2, NA61-6, NA61-10, NA61-11, and NA61-13). All were identified by the senior author who studied collections from various areas of the United States. Waban is resistant to only one of these five NA61 races (NA61-10).

CONCLUSIONS

Sixteen possible NA61 races can be identified by using the four differential varieties comprising the NA61 set of supplemental leaf rust differentials[3] in a dichotomous key. Fourteen of these races were encountered in the studies reported here. Another was found in studies made at Winnipeg, Manitoba, Canada[4]. It is evident, then, that in the North American area there are genes for virulence not differentiated on the standard leaf rust differentials which can be identified by the NA61 supplemental differentials. Since the varieties chosen as supplemental differentials have been or are being used as sources of resistance to leaf rust in the North American area, the identification and classification of races on these differentials will be valuable.

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[4] Personal communication (D. J. Samborski to C. O. Johnston).

PHYSIOLOGIC RACES OF PUCCINIA GRAMINIS IN THE UNITED STATES IN 1960[1]

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Abstract

Race 56 was predominant among 14 races of wheat stem rust (Puccinia graminis var. tritici). This race comprised 67% of 721 uredial isolates identified; race 15B, 17%; 11, 7%; 29, 4%; and 10 other races together, 5%.

Race 15B was most common in the spring wheat region where it comprised 27% of the isolates. There were at least five groups of isolates of 15B which can be differentiated on supplemental varieties. Two of the groups attack Selkirk and were the most prevalent.

Certain isolates of race 11 are virulent on seedlings of line II-50-17 of Frontana x (Kenya 58-Newthatch) and Bowie.

Races 6 and 7 of oat stem rust (P. graminis var. avenae) each comprised 23% of 130 isolates identified. This was the first year in 11 consecutive years in which race 7 has been equaled in prevalence by another race. Race 2 (with the closely related race 5) totaled 20% of the isolates; race 8(with 10), 14%; 7A, 11%; other races, 9%. The virulent race 6A, found for the first time in this country, was collected in Maine, New York, and Illinois. Two new races, tentatively designated 2A and 5B, attack oats having the so-called Canadian type of resistance.

Among 77 aecial isolates of wheat stem rust, 16 races were identified, 7 of which were found only on barberry. Races 11, 15B, 29, and 56 were isolated most frequently. Among 10 aecial isolates of oat stem rust, 6 races were identified.

WHEAT STEM RUST

Four races of Puccinia graminis var. tritici, 56, 15B, 11, and 29 in order of prevalence, comprised 95% of the 721 isolates from 585 collections of wheat, barley, and grasses (Table 1). The remaining 5% included 10 other races. Race 56 comprised 67% of the isolates, an increase of 35% compared with 1959. Race 15B comprised 17%; race 11, 7%; and 29, 4%, a decrease of 18% (see Fig. 1).

The most striking shift in race prevalence was the increase of race 56. This race has not been so abundant in the United States since 1947, when it comprised 69% of the isolates. In 1960 it was particularly prevalent in the soft red winter wheat region, where it comprised 87% of the isolates (Table 2), compared with 9% in the same region the previous year. In the hard red winter-wheat region, race 56 comprised 74% of the isolates and accounted for most of the loss in Kansas and Nebraska of 2 and 5%, respectively. In the spring wheat region, 52% of the isolates were race 56, but it was collected mostly from winter wheat, barley, and Hordeum spp.

Race 15B, the most prevalent race during 1950-1957, increased slightly to 17% of the isolates in 1960. It was found in 16 States of 23 sampled from Nebraska eastward to New York and southward to Texas. This race was scarce in plots in northeastern Mexico (Rio Bravo, Monterrey, and Saltillo)[4] and in Texas outside of experimental plots at College Station and Prairie View, where 16 of the 17 Texas isolates of 15B were collected. In the spring wheat region, however, 15B comprised 27% of the isolates. Most of them came from durum varieties or

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[1]Paper No. 4595, Scientific Journal Series, Minnesota Agricultural Experiment Station. Cooperative investigations with the United States Department of Agriculture.

[2]Plant Pathologists, Plant Pest Control Division, Agricultural Research Service, United States Department of Agriculture.

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E. C. Stakman continued his leadership in the search for supplemental differential varieties and assisted in race identification at various times. Acknowledgment for collections is made to Donald G. Fletcher and E. B. Hayden of the Crop Quality Council and to personnel of the Crops Research Division and the Plant Pest Control Division, Agricultural Research Service, and of the State Universities and Departments of Agriculture.

[4]Race 15B was prevalent in plots at Ciudad Obregon (Sonora), Chapingo and Toluca (Mexico), although less common at La Piedad (Michoacan).

Table 1. Physiologic races of Puccinia graminis var. tritici isolated from uredial collections in the United States in 1960.

State	Race and number of times isolated														Total number of--		
	11	15	15B	23	29	32	38	48A	56	59	59A	59C	102	139	Isolates	Races	Collections
Arkansas	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1	1
Colorado	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	1	1
Georgia	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1
Illinois	2	-	5	-	-	-	-	-	47	-	-	-	-	-	54	3	47
Indiana	-	-	1	-	4	-	-	-	17	-	-	-	-	-	22	3	19
Iowa	1	-	7	-	-	-	-	-	21	-	-	-	-	-	29	3	21
Kansas	8	1	9	-	2	-	-	-	78	-	-	-	-	-	98	5	82
Kentucky	1	-	-	-	-	-	-	-	2	-	-	-	-	-	3	2	2
Michigan	-	-	2	-	1	-	-	-	25	-	-	-	-	-	28	3	25
Minnesota	11	4	32	1	7	-	-	1	40	-	-	-	-	-	96	7	71
Missouri	3	-	5	-	2	-	1	-	36	-	-	-	-	-	47	5	36
Nebraska	3	2	6	-	1	1	-	-	62	-	-	-	-	-	75	6	66
New York	-	-	2	1	1	-	-	-	1	-	3	1	1	-	10	7	6
North Dakota	8	5	17	-	1	-	-	-	19	-	-	-	-	-	50	5	37
Ohio	-	-	-	-	-	-	-	-	16	-	-	-	-	-	16	1	16
Oklahoma	1	-	1	-	-	-	-	-	9	-	-	-	-	-	11	3	9
Pennsylvania	-	-	3	-	1	-	-	-	4	1	-	1	1	1	12	7	10
South Dakota	3	1	10	-	3	-	-	-	52	-	-	-	-	-	69	5	58
Texas	4	1	17	-	8	-	-	1	20	-	-	-	-	-	51	6	39
Virginia	-	1	2	-	-	-	-	-	2	3	1	1	-	-	10	6	6
West Virginia	-	-	-	-	-	-	-	-	1	1	1	-	-	-	3	3	2
Wisconsin	3	-	1	-	1	1	-	-	23	-	-	-	-	-	29	5	25
Wyoming	-	-	-	-	-	-	-	-	5	-	-	-	-	-	5	1	5
Totals	49	15	120	2	32	2	1	2	482	5	5	3	2	1	721	14	585
Percentage	6.8		16.6		4.4		0.1		66.9		0.7		0.3		100.0		
of isolates		2.1		0.3		0.3		0.3		0.7		0.4		0.1			

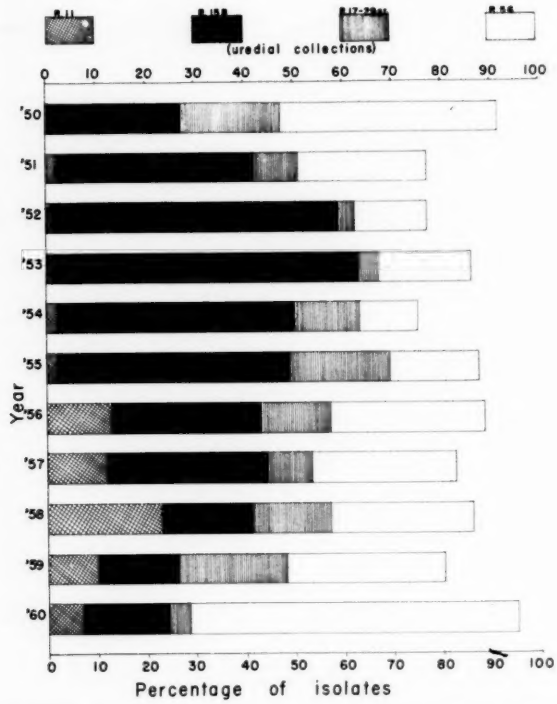

FIGURE 1. Puccinia graminis var. tritici: Relative prevalence of races 11, 15B, 17-29 group, & 56 in the United States 1950-1960

Table 2. Regional distribution of the six most prevalent races of Puccinia graminis var. tritici in the United States in 1960.

Region[a]	Race and percentage of total isolates						
	11	15	15B	29	56	59[b]	other
Spring wheat	10	5	27	5	52	--	1
Hard red winter wheat	7	1	13	4	74	--	1
Soft red winter wheat	2	--	7	4	87	--	--
East central	3	3	18	5	26	35	10
Percentage of total isolates in U.S.	7	2	17	4	67	2	1

[a]Spring wheat region includes Minnesota, North Dakota, and South Dakota. Hard red winter wheat region includes Colorado, Iowa, Kansas, Missouri, Nebraska, Oklahoma, Texas, Wisconsin, and Wyoming.

Soft red winter wheat region includes Illinois, Indiana, Michigan, and Ohio.

East Central region includes Kentucky, New York, Pennsylvania, Virginia, and West Virginia.

[b]Includes races 59, 59A, and 59C.

Selkirk wheat. Although rust was scarce on Selkirk, collections were made generally where trace amounts could be found.

There were at least five groups of isolates of 15B which can be differentiated on seedlings of supplemental varieties at moderate temperatures (70° to 75° F) and which have been tentatively designated as 15B-1, 15B-2, 15B-3, 15B-4, and 15B-5. Of the five groups, two attack Selkirk and were the most prevalent in 1960. The increase in prevalence of isolates that attack Selkirk

Table 3. Physiologic races of Puccinia graminis var. avenae isolated from uredial collections in the United States in 1960.

State	Race and number of times isolated												Total number of:		
	1	2	2A	4A	5	5B	6	6A	7	7A	8	10	isolates	races	collections
Idaho	-	-	-	-	-	-	-	-	-	-	1	-	1	1	1
Illinois	-	1	-	-	-	-	1	1	-	-	-	-	3	3	1
Iowa	-	2	-	-	-	-	1	-	7	-	2	1	13	5	10
Kans.	-	1	-	-	1	-	3	-	2	-	2	-	9	5	8
Maine	-	-	-	1	-	-	-	1	-	-	-	-	2	2	2
Minn.	-	2	-	-	-	-	1	-	5	5	-	1	14	5	12
Miss.	1	-	-	-	-	-	-	-	-	-	-	-	1	1	1
Mo.	-	2	-	-	-	-	3	-	6	-	3	1	15	5	12
Nebr.	-	1	-	-	-	-	-	-	1	-	1	-	3	3	2
N. Y.[a]	-	-	-	1	-	-	1	3	3	-	-	-	8	4	7
N. Dak.	1	-	-	-	1	-	-	-	2	6	1	-	11	5	9
Okla.	-	1	-	-	1	-	-	-	-	-	-	-	2	2	2
Pa.[b]	-	2	-	-	-	-	1	-	1	-	1	-	5	4	3
S. Dak.	-	1	1	-	1	1	17	-	2	4	1	-	28	8	22
Tex.	-	4	-	-	3	-	2	-	1	-	1	-	11	5	8
Va.[c]	-	2	-	-	-	-	-	-	-	-	1	-	3	2	3
Wis.	-	-	-	-	-	-	-	-	-	-	1	-	1	1	1
Total	2	19	1	2	7	1	30	5	30	15	15	3	130	12	104
% of isolates	1.5	14.7	0.8	1.5	5.4	0.8	23.1	3.8	23.1	11.5	11.5	2.3	100.0		

[a]From two aecial collections, race 7 was isolated twice and 5 and 8 once each.
[b]From two aecial collections, races 1 and 2 were isolated once each.
[c]From three aecial collections, races 1, 2, 2A, and 7 were isolated once each.

is important because of their potential threat to the 10 million acres of this bread wheat in the United States and Canada.

Race 11 was widespread, and certain isolates are virulent on seedlings of line II-50-17 of the hitherto highly resistant Frontana x (Kenya 58-Newthatch) and on Bowie wheat. If these isolates increase in prevalence, they could constitute a threat to varieties now being developed. Although race 11 decreased slightly in prevalence from the previous year, it was collected in 13 of 23 States sampled and ranked third in prevalence in the spring wheat region (Table 2).

Race 29 and the 17-29 complex decreased from 22% in 1959 to 4% in 1960. It was found in 12 States of 23 sampled and comprised about 4% of the isolates in each of the four regions but was most prevalent in Texas.

Race 15 comprised 2% of the isolates and was collected in seven States. Certain isolates of this race are virulent on seedlings of Langdon and Selkirk wheat at 70° to 75° F.

The diversity of races identified from the east-central region was particularly striking in 1960. Of the 11 races identified in this region, five were not found in other regions. Many of the uredial samples were collected near barberry or in barberry areas, which again illustrates the diversity of races in barberry areas.

In addition to the 12 standard differential varieties, 7 supplemental differential varieties were inoculated with all collections of rust identified in 1960. These supplemental varieties have become increasingly important in detecting new and virulent rust cultures. The seven varieties are Lee (C.I. 12488), Bowie (C.I. 13146), Selkirk (C.I. 13100), Golden Ball (C.I. 5059), Kenya Farmer (C.I. 12880), Frontana x(Kenya 58-Newthatch) Line II-50-17) (C.I. 13155), and Yuma (C.I. 13245).

OAT STEM RUST

Twelve races of Puccinia graminis var. avenae were identified in 104 rusted collections of oats and wild grasses (Avena spp. and Dactylis glomerata) from 17 States (Table 3). Among the 130 isolates identified, races 6 and 7 each comprised 23%. This was the first year in 11

Table 4. Physiologic races of Puccinia graminis var. tritici isolated from aecial collections in the United States in 1960.

State	Race and number of times isolated																Total number of:		
	11	15	15B	17	29	32	36	38	48A	48B	54	56	102	121	125	176	isolates	races	collections
Iowa	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2	2	2
Michigan	-	-	1	-	-	1	-	-	-	-	-	1	-	1	-	-	4	4	1
Minnesota	-	-	3	-	1	-	-	-	-	-	-	1	-	-	-	-	5	3	3
New York	1	-	1	1	1	-	-	-	-	-	-	2	-	-	-	-	6	5	5
Oregon	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	1	1
Pennsylvania	-	-	3	-	2	-	-	-	-	-	-	4	-	-	-	1	10	4	10
Vermont	-	-	2	-	1	-	-	-	-	1	1	2	-	1	-	-	8	6	3
Virginia	-	-	-	-	3	-	1	-	-	-	-	-	-	-	-	-	4	2	4
Washington	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	3	2	2
Wisconsin	3	1	11	-	8	-	-	1	1	-	-	6	2	-	1	-	34	9	18
Totals	7	1	21	1	19	1	1	1	1	1	1	16	2	2	1	1	77	16	49

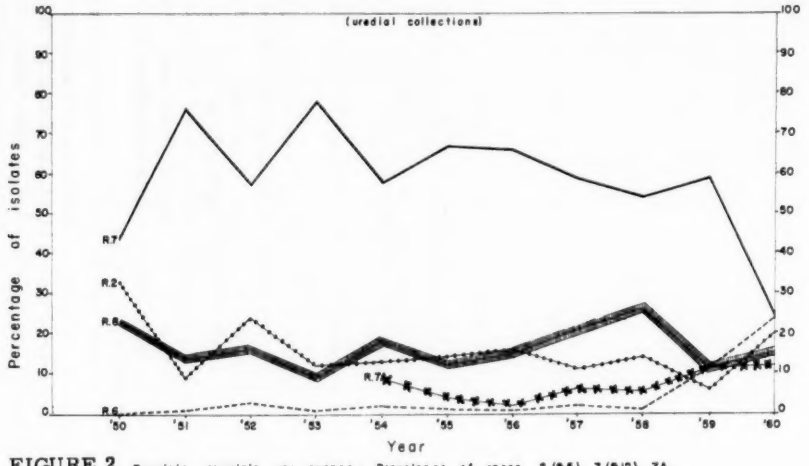

FIGURE 2. Puccinia graminis var. avenae: Prevalence of races 2 (8.5), 7 (8.12), 7A, 8 (8.10), and 6 (8.13) in the United States, 1950-1960

consecutive years in which race 7 has been equaled in prevalence by another race. This race (with the closely related race 12) decreased by 36% from the previous year; and race 6 (with race 13) increased by 13%. Race 2 (with 5) totaled 20% of the isolates, an increase of 13%. Race 8 (with 10) increased from 11 to 14%. Race 7A comprised 11%, a slight increase (see Fig. 2).

The results in 1960 confirm those of 1959 with respect to the wide distribution of race 6, which for many years before 1959 was found almost exclusively near barberry.

The virulent race 6A, first described by Peturson, Green, and Samborski[5] in Canada, was found in the United States for the first time in 1960: in barberry areas of Maine and New York and independently of barberry at Urbana, Illinois. This race can attack virtually all commercial oat varieties that are dependent on genes A, BC, D, and E for their resistance. Moreover, race 6A can be further subdivided by the effects of different isolates on the oat variety Saia.

Race 7A, which attacks oat varieties with the so-called Canadian type of resistance (for example, Rodney), was found only in Minnesota, North Dakota, and South Dakota, compared with nine States in 1959.

Race 4A, found for the first time in the United States in 1959, was isolated once each from oats at Orono, Maine and Clinton, New York, both barberry areas.

Two new races were identified, tentatively designated 2A and 5B, both of which attack Rodney oats. Race 2A was obtained from barberry in Virginia and from oats in South Dakota. Race 5B was isolated from a fall collection of oats in South Dakota.

Seven varieties or lines of oats in addition to the four standard differential varieties were inoculated with all collections of rust identified in 1960, as follows: Rodney (C.I. 6661), Burnett (C.I. 6537), Garry (C.I. 6662), Minnesota '53 Ag. 331 (C.I. 7144), Minnesota '53 Ag. 313 (C.I. 7145), Clinton[2] x Arkansas 674 (C.I. 6643), and Saia (C.I. 4639). The seedling reactions of these varieties or lines to isolates of stem rust and their respective resistant genotypes were given in the report for 1959[6].

RUST FROM BARBERRY

Sixteen races were identified among 77 isolates of wheat stem rust from 49 aecial collections from barberry (Berberis canadensis and B. vulgaris) (Table 4). This is a ratio of 1 race to 3 aecial collections compared with 1 race to 42 uredial collections. Races 11, 15B, 29, and 56 were identified more frequently than other races. Seven races were found only on barberry: 17, 36, 48B, 54, 121, 125, and 176. The identification of race 17 is noteworthy. During the period 1954-1960 it had been supplanted by the closely related race 29; now it appears that 17 might have been resynthesized on barberry.

Six races of oat stem rust were isolated from seven aecial collections from New York, Pennsylvania, and Virginia (Table 3, footnotes).

PLANT PEST CONTROL DIVISION, AGRICULTURAL RESEARCH SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE, IN COOPERATION WITH THE MINNESOTA AGRICULTURAL EXPERIMENT STATION, ST. PAUL, MINNESOTA

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A COMPARISON OF PREPLANT SOIL TREATMENT CHEMICALS FOR CONTROL OF BURROWING NEMATODE IN CITRUS GROVES[1]

R. F. Suit[2]

Abstract

The results from field experiments in progress since 1956 indicate that DCP at 45, 60, or 70 gallons, DBCP at 10 gallons technical, and EDB at 15 gallons (83% toxicant) per acre have controlled the burrowing nematode in citrus groves for as long as 4 years from the time of treatment when used as a single preplant soil treatment in the pull and treat procedure. These appear to be as effective as D-D at 60 gallons per acre which is currently used in the control program. A test of five other nematocides in single quarter-acre plots showed that DCP + EDB at 37.5 gallons (31 gallons DCP + 6.5 gallons 83% EDB), VC-13 at 30 gallons (75% toxicant), S-1283 at 18 and 36 gallons (2.5 pounds toxicant per gallon), and S-1295 at 18 and 36 gallons (2.5 pounds toxicant per gallon) per acre have been satisfactory for 4 years while DCB at 60 gallons of the 40% formulation per acre did not give complete control of R. similis.

INTRODUCTION

Preplant soil treatment as a possible control for spreading decline of citrus trees was first used in an experiment started in 1948 (6). In 1950 the pull and treat procedure utilizing preplant soil treatment was proposed as a control for this disease under field conditions (6). It was not, however, until 1953 that the disease was found to be caused by the burrowing nematode, Radopholus similis (Cobb) Thorne (3). The nematocide 1,3-dichloropropene-1,2-dichloropropane (D-D) was used in these early experiments and in the pull and treat experiments carried out since 1951 (2, 4, 5). Experiments have been in progress since 1956 to determine whether other nematocides are effective in the pull and treat procedure. The first examination of the plots was completed during the summer of 1960 and the results of these experiments are summarized in this report.

MATERIALS AND METHODS

Nine nematocides are being tested in the experiments. The chemical name, pertinent information relative to the formulation used, and the source of each are given in Table 1.

Experimental plots were established in areas known to be infested with R. similis and not more than 30 days elapsed between the date of tree removal and soil treatment. A 3-shank soil treater was used for plots of 1/2 acre or less in size while the 5-shank treater of the Division of Plant Industry, Florida State Department of Agriculture, was used for the larger plots. Both soil treaters had shanks on 18-inch centers and injected the chemicals at a depth of 12 inches.

Experiment A: Plots 1 through 10 (1/2 acre) and plots 11 through 18 (1/4 acre) were treated with the various nematocides on August 9-10, 1956 (Table 2). Since the experiment was in a private grove and R. similis was to be controlled it was not possible to include nontreated plots. The plots were kept fallow by disking biweekly for 6 months and on March 11-12, 1957 were planted with certified nematode-free nursery trees (Valencia on rough lemon rootstock). The trees were hot-water treated (1) before planting as an added precaution to reduce the possibility of introducing R. similis with the trees. The 1/2-acre plots contained 36 trees and the 1/4-acre plots 18 trees, exclusive of border trees.

Experiment B: To compare further the effectiveness of D-D and DCP for preplant soil treatment, four plots were treated on May 14, 1957, following removal of the diseased trees. Plot 1 (3 acres) received DCP at 45 gallons and Plot 2 (3 acres) DCP at 60 gallons per acre, while Plot 3 (2.45 acres) and Plot 4 (6 acres) received D-D at 60 gallons per acre. As in the previous experiment, the plots were kept fallow with biweekly disking for 6 months. Grapefruit or orange trees (certified nematode-free) were planted in the plots on March 17 to 19, 1958.

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[1]Florida Agricultural Experiment Station Journal Series No. 1262.

[2]Plant Pathologist, Florida Citrus Experiment Station. The writer is grateful to personnel of the Division of Plant Industry, Florida State Department of Agriculture and Plant Pest Control Division, Agricultural Research Service, United States Department of Agriculture for assistance in soil treatment and sampling of trees in the larger plots.

Table 1. Nematocides under test as preplant soil treatment for control of R. similis.

Chemical	Code	Formulation: toxicant content	Formulation: trade name	Source
1,3 dichloropropene-1,2 dichloropropane	D-D	100%	D-D Soil Fumigant	Shell Chemical Co.
Ethylene dibromide	EDB	83%	Dowfume W-85	Dow Chemical Co.
1,2 dibromo-3-chloropropane	DBCP-A	97%	Nemagon	Shell Chemical Co.
	DBCP-B	4.3 lb/gal	Fumazone 48	Dow Chemical Co.
1,3 dichloropropene	DCP	100%	Telone	Dow Chemical Co.
1,3-dichloropropene + ethylene dibromide	DCP + EDB	5 parts DCP 1 part EDB by volume	Dorlone	Dow Chemical Co.
O,2,4-dichlorophenyl O,O,diethyl phosphorothioate	VC-13	75%	VC-13 Nemacide	Virginia-Carolina Chemical Co.
1,2 and 1,4 dichlorobutene	DCB	40%	EN DCB-40	Union Carbide Chemical Co.
1,4-dichloro-2-butyne	S-1283	2.5 lb/gal	S-1283	Dow Chemical Co.
3-bromo-propyne	S-1295	2.5 lb/gal	S-1295	Dow Chemical Co.

Table 2. Control of R. similis by preplant soil treatment with nine nematocides.

Plots	Material	Gallons formulation per acre	Trees positive for R. similis, 1960
1 and 9	DBCP-B	40	0 and 0
2 and 6	DCP	60	0 and 0
3 and 10	DCP	40	0 and 0
4 and 7	EDB	15	0 and 0
5 and 8	D-D	60	2 and 0
11	DCP + EDB	37.5	0
12	S-1283	18	0
13	S-1295	18	0
14	DCB	60	3
15	S-1283	36	0
16	VC-13	30	0
17	DBCP-A	10	0
18	S-1295	36	0

Experiment C: DCP was substituted for D-D in one of the regular pull and treat procedures for control of spreading decline in a private grove. In this instance, 3.5 acres was treated with DCP on April 2, 1957. The dosage was to be 60 gallons per acre but after treatment was completed it was found that about 70 gallons per acre had been used. The area was replanted in February 1959.

RESULTS

Experiment A: Approximately 4 years after soil treatment and 3 1/4 years after planting, root samples were taken on June 22 to July 8, 1960 from all trees. R. similis was found in two adjacent trees in Plot 5, one of the duplicate 1/2-acre plots treated with D-D, and in three trees in Plot 14, a single 1/4-acre plot treated with DCB, Table 2. All other plots were free of R. similis. All border trees that were also in treated soil where the treatments overlapped, except two trees in the borders of Plot 14, were free of R. similis. Because the experiment was in a private grove, the areas occupied by infected trees and one row of adjacent trees were treated with D-D at 100 gallons per acre in an attempt to eliminate the infestation. Examination of the plots will be made in 1961 and 1962 to determine whether they have remained free of R. similis for 5 years. If this occurs, R. similis can be considered eliminated.

Experiment B: Four 25-tree sections were selected at random in each plot and the roots of each sampled July 26 to 28, 1960, 3 years after soil treatment and 2 1/3 years after planting. All samples were negative, indicating that the plots were free from R. similis as of that date. Subsequently, the plots were thoroughly sampled by personnel of the Plant Pest Control Division, Agricultural Research Service, United States Department of Agriculture and all samples were free of R. similis. These results show that D-D and DCP controlled R. similis for at least 3 years from the date of treatment.

Experiment C: A root sample from each of the 242 trees was taken on July 21, 1960 by personnel of the Plant Pest Control Division, and all were found to be negative for R. similis. In this instance the DCP controlled R. similis for 3 years from time of treatment.

DISCUSSION

Since R. similis occurs in the soil to depths of 12 feet or more, it is possible that a small population could escape the effect of a chemical soil treatment. Citrus roots will live in the soil at various depths for a number of years after trees have been removed. If all the roots and nematodes were not killed by the chemical used for soil treatment, a few feeder roots would grow which could serve as food for R. similis. If such were the case, nematodes could work back gradually toward the upper soil layers and attack the roots of replanted citrus trees. Therefore, to evaluate properly the efficacy of a nematocide for preplant soil treatment in the pull and treat procedure, young trees should be sampled for at least 3 to 5 years after replanting. Where two adjacent trees show the presence of R. similis following treatment as in Plot 5, Table 2, there is also the possibility of some type of failure in the treatment procedure.

The interval between replanting and the first sampling of the plots in the experiments reported herein varied from 1 1/2 to 3 1/4 years, while the interval from the time of treatment would be 1 year longer with reference to Experiments A and B and 2 years longer in Experiment C. This first sampling indicated that DCP gave satisfactory control of R. similis at the rates used for the period of time given in the three experiments. D-D controlled R. similis except for two adjacent trees in one of the duplicate plots in Experiment A. Previous results with D-D have been satisfactory (2, 4). DBCP and EDB were also satisfactory for control of R. similis as indicated by the results from duplicate 1/2-acre plots in Experiment A. In single quarter-acre plots (Table 2), four other nematocides have been satisfactory for 3 years while DCB did not give complete control of R. similis at 60 gallons of the 40% formulation per acre. Subsequent examination of the plots for the next 2 to 3 years will be necessary to obtain a better evaluation. At present all but one of the nematocides under test appear satisfactory.

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ERADICATION OF THE BURROWING NEMATODE, RADOPHOLUS SIMILIS, FROM BANANAS

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Summary

In Panama and Jamaica Radopholus similis is highly specialized in host selection, and bananas are infected only under field conditions. The race of R. similis so prevalent in Central America and Jamaica is the banana race described from Florida. Citrus interplanted with heavily infected bananas remained unattractive to the nematode even though banana and citrus roots were interlaced. A 5-month rotation to sugarcane, following immediately on the removal of heavily infected bananas, eradicated the nematode pest. Nine-month-old Lacatan plants established from nematode-free rhizomes after the rotation were free of burrowing nematode infection. Abandonment of R. similis infected land to weeds and grasses, or to sugarcane, following complete removal of bananas, eradicated the nematode in 10 weeks. Longevity periods for gravid and unselected females, males and juveniles of R. similis in distilled water and in soil under laboratory conditions are discussed.

INTRODUCTION

Bananas are grown extensively in Central and South America, West Indies, Dominican Republic, Africa and Australia. The Gros Michel variety is preferred to any other, but because of its high susceptibility to Fusarium wilt disease, in the West Indies it has been almost entirely replaced with the wilt-disease immune variety Lacatan, and in the Republic of Panama is in the process of replacement over large areas. Two other varieties, Robusta and Media Marta, are also in increasing production for the same reason.

Radopholus similis (Cobb, 1893) Thorne, 1949, the burrowing nematode, is a serious pest and common in most banana plantations. The nematode was recorded on Gros Michel, Cocos and Lacatan varieties by Loos and Loos (12) and on Media Marta, Ladies Finger and plantain by Holdeman (7).

DISSEMINATION OF R. SIMILIS

R. similis is not indigenous to the western banana areas and was most likely moved from country to country on infected planting material. River water, for irrigational purposes and as a result of flooding after heavy rains, has assisted in the spread of the pest. Holdeman (7), in a survey of banana holdings of a large company operating in Central and South America, found 100% of the plants infected in Guatemala, 90% in Colombia and Ecuador, Costa Rica and Honduras lying in between with heavy to light infections.

PHYSIOLOGICAL RACES

R. similis is a pest of citrus in Florida, of pepper in Banka, Indonesia, of tea in India and of sugarcane in Hawaii. DuCharme and Birchfield (6) and Suit and DuCharme (16) reported on two physiological races. One, the banana race, did not parasitize citrus, while the other parasitized both citrus and bananas. They suggested that the existence of physiological races could explain some of the variation that occurred in severity of disease expression among affected groves. The initial non-attractiveness of Gros Michel to R. similis, bred for many generations on Lacatan bananas, may be attributed to the same condition (9). Similar specializations between banana varieties were evident in the field although definite experimental proof of varietal specialization is still lacking.

NEMATODE SURVEYS

A survey in the Republic of Panama and in Jamaica of virgin and/or lands which did not carry bananas for many years failed to reveal R. similis. However, occasional mats (Ladies

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The work reported was done in Panama and Jamaica.

Finger and Gros Michel) growing near squatters' homesteads were infected. Those infections were undoubtedly brought in by the squatters on infected planting material.

Water grass (Commelina sp.), grown as a ground cover, and coco yam (Colocasia antiquorum), often interplanted with bananas in Jamaica, were found on numerous occasions to be unattractive to R. similis even though infected bananas roots interlaced with their root systems. Citrus is grown in mixed cultivation with bananas in many Jamaican plantations; many examinations of these plant roots for R. similis were negative, indicating that the banana and not the citrus race is prevalent in Jamaica.

Sugarcane (Saccharum officinarum), a major agricultural crop in Jamaica, is generally grown in rotation with bananas. R. similis was recorded from sugarcane by Cobb (5) in 1915, and since then has been mentioned by other workers (4, 14). Numerous examinations of sugarcane roots from several locations in Jamaica failed to reveal R. similis, although Pratylenchus zeae Graham and Meloidogyne spp. were pests. P. zeae was never recovered from banana roots though found frequently in soil samples (10), indicating persistence of the pest on grasses or weeds growing in close association with bananas.

LONGEVITY STUDIES

In Water: Loos (8) found that R. similis disappeared from soils that were continuously flood-fallowed for 5 months or more. Under laboratory conditions, with the water spot method (11), longevity periods were 9 weeks for unselected females, 6 weeks for gravid females and 7 weeks for males (Table 1). Deaths commenced from the third week, and mortality increased rapidly until at the end of the fifth week only 10% survived. Body fat was gradually consumed as the period of starvation increased and was generally completely exhausted prior to death. Esophagus, intestine, ovaries or testes and other internal organs were clearly visible in these fat-depleted specimens. Longevity periods corresponded closely with Birchfield's (3) estimation for the citrus race in Florida.

Large juveniles (pre-adult female stage) that completed the final molt in water survived up to 5 weeks; males molting under similar conditions survived 4 weeks. On the other hand second stage larvae, hatched from eggs laid in water, starved to death in 12 days. Fat accumulations disappeared rapidly. These young larvae did not molt in water.

In Soil under Controlled Conditions: Birchfield (3) found that R. similis survived 4 months when infected citrus roots were buried 3 feet deep in soil trenches. That period included a possible month when small feeder roots, in which the nematode feeds, persisted. Tarjan (17) found that R. similis could not survive more than 6 months in sandy soil of Central Florida in the absence of susceptible roots. He obtained total kills in the top 2 feet of soil in less than 2 months, though, for an unexplained reason, life spans appeared to increase at lower depths. In Jamaica, under laboratory conditions, nematodes in cans of soil were starved to death in 8 weeks, with the majority of deaths occurring between the third and fifth weeks.

Table 1. Longevity of Radopholus similis in distilled water. Results expressed as survivors at different starvation periods. Water changed every 3 to 4 days.

Experiment no.	Days of starvation: 0	7	14	18	21	24	28	35	38	42	49	56	63
Unselected females													
1	88	87	84	64	60	53	27	4	1	1	0		
2	19	19	19	18	18		14	10	7	5	2	1	0
3	51	51	51		35		11	4	0				
Gravid females													
4	40	40	40		22			2	0				
Males													
5	42	42	41	40	38	29	9	4	0				
Total	240	239	235		173		63 [61]	22 [24]	7 [8]	6	2	1	0
% surviving		100	98		72		26	9	3	3	1	0.4	0

ERADICATION OF R. SIMILIS

Three essentials are necessary for establishing R. similis-free banana farms: R. similis-clean land, R. similis-free planting material, and elimination of contamination from outside sources.

Clean Land

Flood-fallowing: This attempted form of control of Fusarium wilt disease is standard practice in many plantations in Central America. Artificial lakes are maintained for 4 to 8 months or, as in more recent practice, for 2 to 3 months, drained and then mold-board-plowed before being reflooded for a further period (1). Loos (8) found that R. similis was completely eliminated in Panama in fields flooded for 5 months. These observations were confirmed later from results of 6-month-flooded areas in the Republic of Honduras (1).

Crop Rotations: Experiment No. 1. To ascertain that burrowing nematodes were completely eradicated under rotational planting with sugarcane, eight plots, each 50 feet by 50 feet, were set up in a 14-month-old cane field, variety B41227, which had a pre-cane-planting history of bananas very severely infected with R. similis. Forty soil samples, five from each of the eight plots, taken 3 weeks after the cane was cleared, were free of R. similis; 37 of these samples had Pratylenchus zeae in fairly large numbers and 21 had Meloidogyne larvae. The eight plots were then planted with bananas, five with pared nematode-free material and the remaining three with regular, unpared, burrowing nematode-infected rhizomes. These plots were in randomized distribution each carrying 16 plants, 8 feet x 8 feet apart. On removal 9 months later all plants in those plots planted with unpared planting material were heavily infested in both roots and rhizomes; on the other hand only four plants of an established stand of 77 in the pared nematode-free rhizome plantings had light infections, and the rest were free of R. similis. Infection of these four plants in the nematode-free plantings were probably contaminations through irrigation water or imperfectly pared rhizomes.

Experiment No. 2: Nine-month-old bananas grown from nematode-free rhizomes, in an area which had been in sugarcane (variety B42231) for 4 months only following a few years of burrowing nematode infected bananas, were found on examination to be free of this nematode pest. Occasional volunteer plants, relics of the previous banana plantation, growing along drain banks in proximity to the experimental plots were heavily infected.

Experiment No. 3: A very severely infected banana field plowed and disk-harrowed to destroy the existing plants and prepare the land for sugarcane planting showed high incidence of R. similis in the soil. Ten weeks later, after planting to sugarcane variety B42231, both soil and sugarcane roots were free of the pest. Volunteer banana plants, sprouting from imperfectly destroyed mats, were still severely infected; however, sugarcane roots interlaced with those infected banana roots were unaffected.

Sugarcane makes a complete ground cover in under 6 months in a good plantation, and under those conditions effectively checks weed growth. This makes it an ideal rotational monocrop.

Abandonment to Weeds and Grasses: A 2-acre block of heavily burrowing nematode infected Lacatan bananas was plowed, disk-harrowed and abandoned to weeds and grasses for 4 months. At the end of that period persistent volunteer bananas were removed and the block disk-harrowed for a second time. One acre was planted immediately with nematode-free Lacatan rhizomes and 4 months later the second acre was planted with similar material. When the banana plants in the 4 months' abandoned plot were 9 months old 53 mats or clumps were removed for examination; 11 plants were infected, 1 severely and 10 lightly. The persistent volunteers, removed at the time the nematode-free rhizomes were planted, were obviously the infecting centers. All 300 banana plants in the plot from which volunteers were destroyed before a further 4-month abandonment before planting with nematode free rhizomes were free of R. similis when examined after 6 months' growth. Root systems were abundant; Meloidogyne incognita acrita was widespread with light infections.

Clean Planting Material

Loos and Loos (12) described the preparation of nematode-free banana planting material. Suitable rhizomes are pared of surrounding tissue until the prepared "seed" is free of discolorations and blemishes. Rhizomes over 4 inches in diameter at the pseudostem base are preferred since germination is markedly reduced in smaller material (8, 12). Nematode-free material used in experiments described in this paper were prepared by that method.

Recontamination

The source of water for flood-fallowing and irrigational purposes is an important factor in the maintenance of R. similis control. Water from deep wells channelled through burrowing nematode-free plantations or through pipes were free of R. similis. On the other hand, water from rivers fed with surface run-off from infected banana land and where bananas were growing along the river banks carried fairly large numbers of R. similis during periods of heavy rain and when the river was in spate. Examination of river water used for irrigational purposes during heavy rains showed three R. similis specimens to 100 gallons of water; spread over a supply of 2 acre-inches this contamination assumes considerable importance.

DISCUSSION

Large-scale production of banana rhizomes free of R. similis infection is best achieved in two or more steps, dependent on the severity of infections at the first paring operations. Infections may enter deep into the rhizome cortical tissues through roots, all of which originate at the central fibrous core. Infection may be a minute red spot in cross section and can be easily overlooked. Such infections can be the nucleus for contamination to the nursery.

In 8 to 10 months, depending on elevation and soil fertility factors, mats will carry up to eight large suckers suitable for propagation to the second step in the nematode-free nursery establishment. Mats are removed and the sucker rhizomes carefully separated from the parent. Any obviously infected material should be discarded at this stage. Larger rhizomes are pared of a thin surrounding layer of tissue and any rhizome with discoloration or blemish discarded. Smaller rhizomes, 2 to 4 inches in diameter across the pseudostem base, from clean mats, are best transferred to isolated beds and planted 1 1/2 to 2 feet apart. A 50 x 4 foot nursery will accommodate over 60 such plants. An application of 1,2-dibromo-3-chloropropane, as Fumazone or Nemagon emulsifiable concentrate at 2 gallons active ingredient per acre, immediately after and again 6 weeks later will reduce and confine a possible contamination brought in with the rhizomes. In 3 to 4 more months rhizome formation will be large enough for paring and transfer to clean nurseries. The first step nursery site can be abandoned, after plowing and disk-harrowing, for 4 to 6 months and then planted again for production. One acre of first stage plantings will give sufficient material at the end of 8 months to plant 5 acres of the second stage nursery. By the rapid multiplication method (2) the acreage can be increased to over 60 in less than one more year. With this nursery as the nucleus of nematode-free certified material, a dozen sub-distribution centers can be commenced 1 1/2 years after the first parings of the original heavily infected rhizomes. On a planned rehabilitation and control program the waiting years can be used for clearing infection sources around the rivers and water channels, by removing and destroying banana rhizomes that are near enough to cause contamination during heavy rains.

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COUNTY OF LOS ANGELES, CALIFORNIA

THE ROLE OF FUNGI IN THE PEACH REPLANT PROBLEM

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Summary

Pathogenic fungi played an important role in the difficult process of establishing peach trees in old peach soil. The most active pathogen found on peach tree roots was Pythium ultimum Trow, which previously had not been described as a pathogen of this host. Isolates of the fungus varied in pathogenicity; the most pathogenic isolates and greater number of the pathogenic strains of Pythium were found in replant problem peach soil than were found in non-replant problem soil as shown by isolation and pathogenicity studies.

The most common fungi on the roots of peach trees in replant peach soil were members of the genera Pythium, Rhizoctonia, and Fusarium.

INTRODUCTION

It is often difficult to replant peaches in old peach soils. This problem has been reported from Canada (6) and several locations in the United States. In California a high percentage of replantings has shown depressions of growth in Sutter, Fresno, Tulare, El Dorado, Kings, and Sacramento counties (4). In the peach-growing section of Solano County there is generally no problem in the Suisun Valley, but it may be severe in the Winters area, only 12 miles north.

Theories as to cause and symptomatology have been reviewed (6), as well as the role of amygdalin breakdown in California soils (5). Several substantiated theories have been advanced as to the cause of the depressed growth which may indicate that several problems are involved rather than a single one, the relative importance of each varying with locale.

Fungus studies in relation to the problem have been few. Wensley (10) made a survey of the rhizosphere fungus flora of five peach orchard sites in Canada. Population patterns were found to be different in each orchard. Fungi reported were members of the common sporulating imperfect genera such as Penicillium, Fusarium, Aspergillus, Paecilomyces, and Trichoderma.

Savage, et al. (9) found a close relationship between the incidence of root rot caused by a species of Clitocybe and the occurrence of the peach replant problem.

Wensley (11) made further studies of the fungi associated with peach orchard soils and the influence of soil fumigation on the fungus flora and the growth of young peach trees. Fourteen species of fungi, out of several hundred isolated from the rhizosphere and root tissues, were described as being facultative parasites on the roots of peach seedlings when grown under greenhouse experimental conditions. Soil fumigation with methyl bromide, as well as 1,3-dichloropropene and 1,2-dichloropropane (D-D), induced greater growth of peach seedlings in most soils than ethylene dibromide or chlorobromopropene (CBP).

MATERIALS AND METHODS

Old peach orchard soils from several locations were studied. Some locations regularly experienced replanting difficulties (replant problem) while others did not (non-replant problem).

Soil Samples: The top 4 inches of surface soil was removed and holes about 18 inches in diameter dug to facilitate sampling at specific depths. Soil was collected at various depths along sides of the hole with a sterile spatula and placed in sterile containers.

Synthetic Soil Mix: The standard U. C. Soil Mix C and fertilizer solution 11 (1) was used as a growth medium for seedling peaches and for the inoculation studies.

Isolation of Soil Fungi: Six techniques for fungus isolation from soils were used. They were: 1) Lovell seedling trees were planted in the field, removed after various periods of time, and isolations made after washing the roots for 36 hours. The roots were then placed on water agar supplemented with streptomycin at 100 ppm. Fungi growing from the roots were hyphal-tipped after 72 hours and placed in tubes. 2) Field soil was brought into the greenhouse and Lovell seedling trees planted. These were removed after various periods of time, and the above procedure used to determine fungi on the roots (trap root technique). 3) Immersion tubes containing 2% water agar base with griseofulvin (2) at 20 ppm and streptomycin at 100 ppm were placed in soil. The soil was brought up to field capacity, and after 5 days the tubes were withdrawn. Discs were cut from the agar cores and placed on 2% water agar supplemented with 100

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ppm of streptomycin. Fungi growing from the discs were hyphal-tipped and placed in tubes. 4) Hemp seed was floated on the surface of water which covered small samples of soil. After 4 days at room temperature the hemp seed was removed from the water and isolations made. 5) Campbell's apple technique. 6) Soil and water were mixed 1 to 1 by volume and drops transferred to the standard isolation medium. Fungi that grew from the soil after 72 hours were hyphal-tipped and transferred to tubes.

Fungi isolated from the soil by use of the techniques described were separated into types based on morphology and growth at different temperatures. The percentage of total isolations for each species was determined by calculating the total number of isolates from each orchard and the total number of times a particular isolate was obtained. The same procedure was used to determine the percentage of total isolations from roots.

The dilution plate studies were made on novobiocin-PDA medium (3).

Pathogenicity of Fungi: The inoculum and inoculations for all pathogenicity studies were prepared as follows: Transfers were made from stock cultures to PDA in Petri dishes. After 5 days of growth on this medium, two plates of each isolate were placed in a Waring Blendor with 200 ml of water and blended several seconds; 50 ml of this mixture was then poured into each of four 4-inch pots that were half filled with U. C. mix; Lovell peach seedlings of uniform size and age were placed in the soil and sterile U. C. mix added to fill the pot. The plants were then thoroughly watered. After 2 weeks they were carefully removed from the soil, the roots washed and examined. A visual recording was made as follows: 0-healthy roots (similar to the check), 1-some root damage, 2-moderate root damage, and 3-severe root damage. The four plants in each series were then cut off below the cotyledons and the roots dried to a constant weight at 90° C. The combined weight of the four root systems was determined on an analytical balance. The percentage of root weight of control was determined from the following relationship:

$$\frac{\text{control weight-treatment weight}}{\text{control weight}} \times 100 = \% \text{ root weight of control}$$

RESULTS

Pathogenicity Studies: P. ultimum was commonly isolated from all roots but there was a difference in pathogenicity exhibited. Data showed that isolates from old peach orchards where replanting was a problem were more pathogenic than those from old peach orchards where there was no replant problem. P. ultimum was isolated from the soil as well as from roots in the replant orchards but usually only from roots in non-replant type orchards. When trap roots were used for isolation from replant soil, 38% of the isolations were P. ultimum, while similar isolations from non-replant soil yielded only 5% of the fungus (Table 1).

Differences in pathogenicity of three isolates of P. ultimum on roots of Lovell peach seedlings are shown in Table 2.

Fungus Population: Since isolates of the genus Pythium were shown to be pathogenic on peach roots, an investigation was made to determine the relative population of the fungus.

Results using the soil and water, hemp trap, soil tube, and apple trap techniques, described previously with soil from three sources and from four depths, are shown in Table 3. The soil-water technique appeared to be the least reliable. The other techniques appeared to be equally reliable in the isolation of Pythium spp. from the three soils in that comparable populations were recovered. Pythium spp. were just as easily isolated from 18-inch depths as from surface levels. The techniques may have been non-quantitative in nature; if so, this could account for the lack of differences at different depths. There were as many isolates of Pythium spp. from replant as from non-replant soil.

Studies were made utilizing the soil dilution plate method: 1) to determine fungi in the site area of a replant problem soil, and 2) to compare quantitatively fungi in the site and intersite area of the same soil to see if differences in fungi could be correlated with differences in growth of peach trees between site and intersite areas.

Soil samples were collected from a plot site area where a depression of growth was noticeable in replanted Lovell seedlings. Suitable dilutions were made on novobiocin-PDA medium. Fungi that could not be identified on the original dilution plates were transferred to V-8 juice agar for identification. Those that remained sterile after 14 days at 25° C were then marked as such. The results of this experiment are given in Table 4.

Similar studies were made in a typical replant problem soil where growth depression was common in the old tree site area but not in the intersite area. A comparison of the number and kinds of fungi was made from the site and intersite area by use of the same technique util-

Table 1. Summary of the occurrence of fungi isolated by different techniques and their pathogenicity from four peach soils.

Isolate	Percentage of total isolations												Visual path. rating				% root weight of control			
	roots				soil				trap roots											
	1	2	3	4[a]	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
P. aphanidermatum								4								0			0	
P. echinulatum								8								0			0	
P. mamillatum					2								0				0			
P. rostratum					17			2					0			0	0		0	
P. ultimum	12	11	15	19	0	0	-[b]	63		5		38	0	2	3	3	0	23	50	54
Pythium sp. 1					27	67	-	10					0	0	3	1	0	0	40	0
Pythium sp. 2					39	3	-	3					0	0	0	0	0	0	0	0
Pythium sp. 3	19		18			9	-						0	0	2		0	0	43	
Fusarium oxysporum	63	65	29	56						63		56	0	0	1	1	0	0	0	0
Ster. Phyco. 1					9	8	-	6					0	0		0	0	0	0	0
Ster. Phyco. 2					4	7	-	2					0	0	1	2	0	0	10	15
Ster. Phyco. 3								2								3				20
Rhizoctonia 1			27	41								4			2	1			43	37
Rhizoctonia 2		7		19										0		1		0		27

[a]1, 2 = typical non-replant problem old peach soil. 3, 4 = typical replant problem old peach soil.
[b]- Indicates isolated but percentage of total isolations not determined.

Table 2. Pathogenicity of three isolates of Pythium ultimum on roots of Lovell peach seedlings.

Isolate	Length of healthy root system[a] (in cm)	Height of seedling from cotyledon to apical bud (in cm)
236	17	40
247	9.8	34
213	4.7	27
Check	21	44

[a]Average of 10 plants.

Table 3. Isolation of Pythium spp. from the soil at different depths using four techniques.

Depth (in inches)	Techniques											
	Soil and water soil			Hemp trap soil			Soil tube soil			Apple trap soil		
	1	2	3	1	2	3	1	2	3	1	2	3
4	20[a]	15	17	10	18	18	20	18	20	20	20	20
8	20	20	15	18	19	19	20	16	20	20	19	20
12	7	0	12	10	19	19	20	17	20	20	20	20
18	5	3	10	17	20	20	19	15	20	20	18	20

[a]Figures in each column represent times isolated from 20 units in each technique.

Table 4. Number and kinds of fungi isolated from a tree site area in a typical replant problem soil on novobiocin-PDA medium (1/4000 dilution).

Fungus	No. of times isolated	Fungus	No. of times isolated
Aspergillus spp.	10	Phialophora sp.	2
Cephalosporium spp.	12	Rhizopus nigricans	12
Cylindrocarpon sp.	4	Sepedonium sp.	2
Fusarium spp.	27	Spicaria sp.	2
Gliocladium roseum	16	Stachybotrys sp.	6
Heterosporium sp.	2	Stysanus stemonitis	34
Isaria spp.	3	Trichoderma lignorum	24
Monosporium sp.	16	Torula sp.	1
Monotospora sp.	1	Volutella sp.	1
Paecilomyces sp.	1	Acrostalagamus cinnabarinus	28
Penicillium spp.	38	Misc. sterile Phycomycetes	6
Periconia sp.	2	Other sterile fungi	22

Table 5. Number and kinds of fungi isolated from a site and an intersite area in a typical peach replant problem soil on novobiocin-PDA medium (1/10,000 dilution).

Fungus	Site	Intersite	Fungus	Site	Intersite
Aspergillus spp.	31	28	Penicillium spp.	59	14
Cephalosporium spp.	7	14	Pyrenochaeta sp.	1	0
Cladosporium sp.	1	0	Rhizopus sp.	1	1
Colletotrichum sp.	1	0	Scopulariopsis sp.	2	0
Cunninghamella sp.	1	0	Stachybotrys sp.	0	2
Fusarium spp.	11	14	Stemphylium sp.	3	2
Hormodendrum sp.	2	0	Trichoderma sp.	7	0
Isaria sp.	3	1	Verticillium sp.	5	4
Monosporium sp.	2	2	Unidentified	15	12
Monotospora sp.	3	3			

ized in the previous experiment. Only fungi on the original dilution plates were identified, however. In this experiment differences were found in two genera, Penicillium and Trichoderma. Both of these genera were more common in the site area than in the intersite area. The fungi found, and the frequency in which they were isolated, are shown in Table 5.

Higher numbers of Penicillium and Trichoderma were found in the site area of replant soil, probably because of the presence of more dead roots and other organic matter. Members of the genus Fusarium, some isolates of which were shown to be facultative parasites in later studies, were not in higher numbers in the site area than in the intersite area.

The importance of this quantitative difference in fungi found in the depression of growth in the site area is doubtful.

Pythium spp. and other Phycomycetes constitute a very minor part of the fungi normally isolated from soil by the dilution plate method, hence they were rarely recorded in this sort of study.

DISCUSSION

The replant problem does not occur in all old peach soils. These studies showed that fungi pathogenic on the small roots of peaches played an important role in the replant problem. This is evidenced by the fact that a quantitative difference existed between pathogenic fungi in replant and non-replant soils. P. ultimum, one of the most active pathogens encountered, was found in higher numbers on the roots of peach trees used as a trap in replant problem sites as compared with non-replant problem sites.

This study indicated that P. ultimum may vary in its ability to attack different hosts. Cultures obtained from grape, for instance, were less pathogenic on peach than those obtained from peach or cherry. Isolates from replant problem soils were more pathogenic than isolates from non-replant problem soils. It is suggested that the substrate, in this case the host, may alter or influence physiologic processes so that pathogenic specialization may develop. Well documented cases of this phenomenon are known with soil fungal pathogens such as Fusarium oxysporum, Rhizoctonia solani (7), and Verticillium albo-atrum (8). Thus, continual development on a particular host might increase pathogenic capabilities for that host. For this reason the species encountered might be the same in replant problem and non-replant problem sites, but pathogenic capabilities of the fungus might be quite different.

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APHIDS AND THE EPIDEMIOLOGY OF BARLEY YELLOW DWARF VIRUS IN NEW BRUNSWICK[1]

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Abstract

Barley yellow dwarf virus (BYDV) was commonly encountered in New Brunswick's small grain fields during the 1960 season. When aphids were collected from BYDV infected plants in the field, Rhopalosiphum padi-fitchii, R. maidis (Fitch), Macrosiphum avenae (Fabr.), and Metopolophium dirhodum (Wlk.) transmitted the virus. In addition, BYDV was transmitted by oviparae of an endemic aphid found on timothy and closely related to the greenbug, Schizaphis graminum (Rond.). A single isolate of BYDV was transmitted by R. padi-fitchii, M. avenae, M. dirhodum, but not by S. graminum. Virus could not be recovered from 60 plants of three perennial grasses which were exposed to the field population of aphids in 1960. In comparison, two out of 20 oat plants were infected by July 15. It is estimated that about one out of every 300 aphids transmitted BYDV to oat plants in an experimental plot.

INTRODUCTION

Following discovery of barley yellow dwarf virus (BYDV), Oswald and Houston (8, 9) recognized two factors which seem to be the key-elements in the epidemiology of the disease. They showed that five aphid species could transmit BYDV and that the virus had a wide host range among Gramineae. Circumstantial evidence suggested that perennial grasses were the foci of BYDV infection from which the virus was carried into the small grain fields. During the past years important advances have been made in the understanding of the virus-vector relationship. Following the work of Toko and Bruehl (18), vector specific strains have been systematically investigated at the Cornell laboratory (11, 12, 13). Recently Rochow reported a specialization among one of the vector species (14). Aspects of the epidemiology of BYDV have been studied by various workers (1, 4, 5, 10, 15, 16). Although these studies have provided some knowledge of the disease much remains to be learned of the mechanism whereby BYDV is introduced each year into the small grain crops.

In the present paper a few observations are recorded that relate to the epidemiology of BYDV in New Brunswick.

OCCURRENCE OF BARLEY YELLOW DWARF AND APHID VECTORS

Yellow dwarf certainly has been present in New Brunswick -- as in many other areas -- for some time. Symptoms of the disease were noticed at the Research Station, Canada Department of Agriculture, Fredericton, for the past 12 years. The wide distribution of BYDV during 1960 has already been noted (6).

Aphid trappings and field observations by the Entomology Section, Research Station, Canada Department of Agriculture, Fredericton, have shown aphids of the Rhopalosiphum padi-fitchii complex the predominant cereal aphid of the area. Populations of Macrosiphum avenae (Fabr.) (=granarium (Kirby)) and R. maidis (Fitch) were of more sporadic occurrence. This pattern also prevailed during 1960; R. padi-fitchii was the most common species and was found in almost all oat fields inspected. On the winter hosts high populations of R. padi were present (Fig. 1). Some aspects of the biology and taxonomy of cereal and grass aphids of the area will be discussed elsewhere.

APHID VECTORS OF BARLEY YELLOW DWARF VIRUS

All species of aphids found on grain plants were tested as vectors of BYDV. After the appearance of symptoms in the field, infected oat and barley plants were searched for the presence of aphids. Thus 10 to 40 apterous or instar aphids of each species were obtained from one or more infected plants, and were transferred in batches of 3 to 4 aphids to single C.I. 666

[1]Supported by a grant from the National Research Council, Ottawa.

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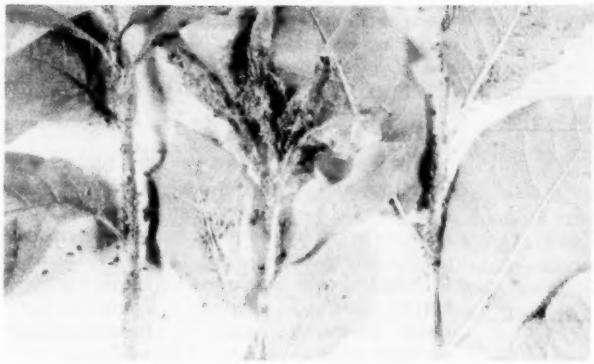

FIGURE 1. Colonies of Rhopalosiphum padi (L.) on its winter host Prunus virginiana.

barley plants. Aphids were left on test plants for 1 to 2 days and were then killed by S-(1, 2-bis(ethoxycarbonyl)ethyl) O, O-dimethyl phosphorodithioate (malathion) spray.

Each of the four species collected in the field transmitted BYDV, since at least one of several test plants developed symptoms of the disease (Table 1). All of these aphids have been previously shown to be vectors of the virus (8).

AN ENDEMIC SCHIZAPHIS GRAMINUM AS VECTOR OF BARLEY YELLOW DWARF VIRUS

The greenbug, Schizaphis graminum (Rondani), has been shown by Oswald and Houston (7) to be a vector of BYDV, and the aphid has been thought to contribute extensively to epiphytotics of the disease (5, 17). The greenbug seems to be rather scarce in the Maritime provinces, but during 1960 a morphologically similar aphid was collected from Phleum pratense. Since it could be separated from S. graminum s. str. by its color, host range, and the production of sexuales, the aphid will be described as S. graminum phlei ssp. n.

Owing to the host specificity of this aphid, summer viviparae did not feed on oats or barley. During fall numerous sexuales were produced and oviparae could be maintained on oats or barley for at least 8 days. After an acquisition feeding on infected barley, 3 to 4 oviparae were transferred to test plants from which 2 out of 17 developed symptoms of BYDV. This indicates a rather low vector efficiency as it has been previously noted for S. graminum s. str. No attempts were made to demonstrate virus transmission by S. graminum phlei among timothy, which is the natural host of the aphid.

In similar tests, another grass aphid, Hyalopteroides humilis (Wlk.), could not be incriminated as vector of BYDV.

TRANSMISSION OF A SINGLE ISOLATE OF BARLEY YELLOW DWARF VIRUS BY FOUR SPECIES OF APHIDS

In view of the frequent occurrence of vector specific strains of BYDV (12, 13), transmission of a single isolate by four species of aphids was tested. A strain of BYDV was obtained from a naturally infected oat plant. Three of the aphid species (Table 2) used in virus recovery were derived from local populations. A fourth kind, S. graminum, originated from Wisconsin, U.S.A., and was kindly supplied by W. F. Rochow, Cornell University, Ithaca, N.Y. Virus-free stock colonies were obtained by the usual method, and these aphids were frequently sampled for the presence of virus. Acquisition feeding was 3 days, inoculation feeding on C.I. 666 barley 1 day.

As shown in Table 2, the isolate of BYDV was transmitted by R. padi-fitchii, M. avenae, M. dirhodum, but not by S. graminum. These results suggest that the isolate of BYDV did not have a marked vector specificity. Rochow has found the majority of BYDV isolates from field samples in New York and several other States to be transmitted by only one or two vector species, rarely by three, and never by all four species (12, 13). In these studies R. maidis has been used for virus recovery instead of M. dirhodum.

That vector specific strains are not rare in New Brunswick was noted when an isolate was transmitted as follows: 20 out of 43 test plants were infected by R. padi-fitchii but none of 43 were infected by M. avenae. This isolate of BYDV has been obtained from a colony of R. padi-

Table 1. Transmission of BYDV by four species of aphids collected from infected grain in the field.

Aphid species	Virus source	No. of plants infected/ no. of plants tested
Rhopalosiphum padi-fitchii	Oats	3/4
Rhopalosiphum maidis	Barley	2/4
Macrosiphum avenae	Oats	2/3
Metopolophium dirhodum	Oats	1/2

Table 2. Transmission of a single isolate of BYDV by four species of aphids.

Aphid species	No. of plants infected/ no. of plants tested
Rhopalosiphum padi-fitchii	4/8
Macrosiphum avenae	7/8
Metopolophium dirhodum	4/8
Schizaphis graminum	0/8

fitchii reared at the Research Station, Canada Department of Agriculture, Fredericton.

INFECTIVITY OF FIELD-GROWN GRASSES AND OATS

A great number of grasses have been incriminated in greenhouse tests as potential carriers of BYDV, but so far relatively few isolations have been made from naturally infected grasses. Slykhuis, et al. (15) have found a number of virus carriers among perennial grasses collected in the field. In Europe naturally diseased grasses have been reported by Watson and Mulligan (20) and Rademacher and Schwarz (10).

In the present work, 20 plants each of Avena sativa (variety Clintland), Phleum pratense, Lolium perenne, and Poa pratensis were planted in two plots of 15 m x 20 m. In one plot flight activity, host preference, and population development of cereal aphids was recorded, but owing to an accidental plowing of the plot, grasses were not available in fall for virus recovery. Grasses of the second plot in which no aphid observations have been made were removed from the field during October and transferred to the greenhouse. For virus recovery tests non-viruliferous R. padi-fitchii, M. avenae, M. dirhodum, S. graminum were fed on leaf samples in test tubes for 2 days and were then transferred to C.I. 666 barley test plants. BYDV could not be recovered from any of the 60 grasses tested, but was observed in 2 out of 20 oat plants growing in the plot from May 12 to July 15.

The outcome of this experiment could have been due to several factors. Recordings made from a comparable plot indicated that cereal aphids, primarily R. padi-fitchii, alighted on the three grasses but were found in smaller numbers on grasses than on oats on which aphids also stayed longer than on grasses (4). Thus quantitative differences in the colonization of the host plants could have accounted for the absence of virus in less suitable grasses. The failure to recover BYDV from any of the grasses could also be explained by the findings of Toko and Bruehl (19) who reported virus recovery difficult from grasses beyond the seedling stage. Grasses in the present experiment were tested several months after removal from the field.

NUMBER OF VIRULIFEROUS APHIDS

The occurrence of BYDV in the cereal crop is related to the density of inoculum in the vector population. Stetson, et al. (16) found an extremely high number of viruliferous aphids: 13 out of 47 R. fitchii (Sand.) and 4 out of 10 M. avenae carried the virus. Similar tests in Wisconsin have indicated that less than 1% of the grain aphid population were viruliferous during early summer of 1957, 1958 (5). In both years an average incidence of BYDV developed. In experiments with potato leaf roll virus, another persistent virus comparable to BYDV, 835 Myzus persicae (Sulz.) infected eight test plants (3). Work with vectors of biologically transmitted animal viruses has likewise shown a considerable variation in the number of virus-carrying insects. Western and eastern equine encephalitides virus has been isolated from 1 out of 25-40 to up to 1 out of 1970 mosquitos tested (2). It can be expected that field infectivity varies with virus, vector, host plant, locality, and season involved.

No tests for isolation of BYDV from field collected aphids were attempted in the present work. Instead, virus density in the vector population was estimated by comparing landings of spring migrants on 20 oat plants in an experimental plot with BYDV incidence in these plants. A total of 298 cereal aphids were recorded on oats during a daily checking schedule from May 17 to July 1, 1960. When aphids on the plants were counted five times daily, an average of 20 left the host in less than a day. This then would amount to an additional 820 aphids for the 42 days of observation, or a total of about 1130 insects. These aphids infected 4 out of 20 plants, or one out of 280 aphids were effective in bringing about virus infection: $\frac{1130}{20} \times \frac{20}{4} = 280$

This estimate is likely conservative, since a number of aphids in the plot took-off unrecorded.

What may appear a low percentage of virus-carrying insects converts into a substantial number of transmitters if field populations are considered, even though viruliferous aphids are believed to be less dispersive than other spring migrants because of a prolonged acquisition feeding (4). Furthermore, not every viruliferous aphid is likely to infect every plant it feeds on.

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IRIS LEAF SPOT CONTROL[1]

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Abstract

The iris leaf spot caused by the fungus Didymellina macrospora Kleb. can be controlled effectively with zineb, maneb or Phaltan. Tests indicate that these materials are about equally effective. In northern West Virginia the fungus usually overwinters as the asexual stage Heterosporium iridis (Fautr. & Roum.) Jacques. Renewed growth of this stage on infected, dead leaves provides the primary inoculum in the spring.

The most widespread disease of bearded iris in West Virginia is the leaf spot caused by the fungus Didymellina macrospora Kleb. Sometimes hundreds of the spots may occur on a single leaf, resulting in a relatively rapid death of the leaf. Usually infection causes plants to be stunted and unthrifty.

Removal of all dead infected leaf material in the fall or in the spring leaves sufficient inoculum to necessitate a spray program if the disease is to be checked. A limited experimental control program was carried out during the 1960 season in a planting of mixed bearded iris varieties.

MATERIALS AND METHODS

The iris planting consisted of several double rows of mixed varieties spaced about 1 foot apart in the row and with a 2-foot spacing between rows. Zinc ethylene bisdithiocarbamate (zineb 75 W), manganese ethylene bisdithiocarbamate (maneb 70 W), and N-trichloromethyl thiophthalimide (Phaltan 50 W) were included in this test; each was applied to five replicated plots on two dates. Five additional unsprayed plots were included as controls. The materials were applied with a small 1 1/2 gallon sprayer of the type that would normally be used for small garden care. Zineb and maneb were used at the rate of 1 level tablespoon per gallon of water and Phaltan at the rate of 1 1/2 level tablespoons. An attempt was made to apply sufficient spray materials to wet all the leaf surfaces. The spreader, Triton B-1956, was added at the rate of 1 ml (20 drops) per gallon (1/5 pint/100 gallons). At this rate the spray readily wet the waxy leaves.

The fungicides were applied on May 16 and again on May 27. An additional planned treatment was not applied because of a dry period early in June. Even better control might have been obtained if the first spray application had been made at least 2 weeks earlier as some buildup of the disease was evident on May 16.

The amount of leaf spot injury was determined on June 29. Since the grower found it necessary to move this planting early in July, data could not be collected later in the season. The number of lesions on 20 leaves from each plot was used as the basis for comparison. Only the tip 12 inches of the leaf was considered and spots in all stages of development were counted. Leaves were selected at random from the plots.

RESULTS AND DISCUSSION

The total leaf spots on the samples from five replicated plots were as follows: zineb, 202; maneb, 183; Phaltan, 242. A total of 901 spots were found on comparable control samples. There was no significant difference in the degree of control obtained with the different fungicides.

Frequent observations indicated that much of the disease present in the sprayed plots originated from infections that had occurred before the first application. Also, that the disease was not so destructive in the unsprayed plots within the treatment area as it was in an adjoining block of iris that was not treated. The control plots averaged 180 lesions per sample of 20 leaves. A total of 3164 were found on 20 leaves of a similar sample taken from the unsprayed block. The difference was at least partly due to the lower inoculum potential within the block containing the sprayed plots.

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[1]Published with the approval of the Director of the West Virginia Agricultural Experiment Station as Scientific Paper No. 656.

Observations in parts of northern West Virginia indicate that the fungus usually overwinters as the conidial stage, Heterosporium iridis (Fautr. & Roum.) Jacques, and that renewed growth and sporulation of this stage provides the primary inoculum in the spring.

A species of Heterosporium also occurred on wild garlic, Allium vineale, growing in the iris plots as a weed. This appears to be the same fungus that attacks the iris and, if so, possibly the garlic serves as a source of infection in some regions.

No evidence of resistance to this leaf spot was observed on the bearded iris types present in this planting.

It was evident that satisfactory control of iris leaf spot could be obtained with each of the fungicides tested. A high degree of control would necessitate a sufficiently early application of the fungicide and repeated treatments during the growing season.

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CONIFER TUMORS IN THE CENTRAL ROCKY MOUNTAINS

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Summary

Tumors occur in epidemic proportions on stems of lodgepole pine and other conifers in northern Wyoming and in scattered stands from Colorado to Montana. No pathogen or insect has been found closely associated with the growths, but their distribution and host range seem to rule out genetic and abiotic factors as causes of tumor formation, and suggest pathogenic origin. Bark and wood in tumors differ only slightly from healthy tissues, but deformed trunks cannot be used for normal purposes.

Several kinds of tumors develop on conifer trunks. Aside from galls caused by known fungi and bacteria, tumefaction usually occurs in association with wounds or other occasional stimuli. Where tumored trees are grouped, mutations and "hereditary predisposition" to environmental factors have been suggested as causes (1). Sequoia commonly bears tumors, but these are at least partly bacterial in origin (1, 2, 4). The only other reports of epidemics of coniferous tumors in North America appear to be those of P. R. White and associates regarding tumors specific to Picea glauca and P. sitchensis (5 et prior).

The present report concerns tumors on trunks and branches of coniferous species -- chiefly lodgepole pine, Pinus contorta--in the Rocky Mountains. Although these growths are apparently unreported in phytopathological literature, they are well known to National Park Service employees because of the conspicuous outbreaks in Yellowstone National Park, Wyoming. Tumorous stands are called "The Knotted Forest" in a recent manual (3), which ascribes the disease to infection by dwarfmistletoe (Arceuthobium americanum). Ellsworth Bethel, mycologist and forest pathologist, blamed the Yellowstone tumors on western gall rust (Peridermium harknessii) in correspondence of the early 1920's.

FIELD DESCRIPTION

Tumors on lodgepole pine in the Rocky Mountains are similar to those described on spruce (1, 6). The cancerous growths first appear "like a half-grain of rice" (6), and increase in size without known limit. The largest observed were about 3 feet in diameter on a 6-inch trunk. Tumors may occur singly but are usually grouped along a trunk or on branches (Fig. 1). Often a tree bears more than 1000 tumors. None have thus far been found on pine roots, but only 10 root systems have been examined. Trees of all ages become diseased. In the Big Horn Mountains (north-central Wyoming) several acres of 5- to 15-year-old pines are 100% tumorous. Nearby are 200-year-old pines that apparently were attacked only when mature, as only branches of the last 25 years bear tumors.

No marked effect on the general health of tumored trees was observed, though some badly deformed trees were dead (from uncertain cause), and a few were girdled where rodents chewed the bark from tumors.

SURVEY

Stands in Bighorn National Forest, Shoshone National Forest, and Yellowstone National Park were examined. For survey purposes, an infested stand was defined as one in which more than 20% of the trunks (all species) bear tumors in the first two 16-foot logs. On this basis the total infested area actually observed in the two national forests was roughly 1500 acres, with perhaps another 100 acres in the Park. On about half of these acres more than 60% of the lodgepole pine were tumorous (counting branch as well as trunk swellings). These are only fractional estimates of the total infested acreage, because no outbreak was explored to its limits, and not all reported outbreaks were visited. Nor were areas of tumorous pine that the writer has observed while driving in Idaho (Boise National Forest) and Montana (near Lolo and Deer-

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Thanks are due to a number of Forest Service and National Park Service personnel, especially L. P. Forman and J. B. Scott (F.S.) and Mrs. Herma A. Baggley (N.P.S., retired) for help in locating tumorous stands.

lodge National Forests) included in this survey.

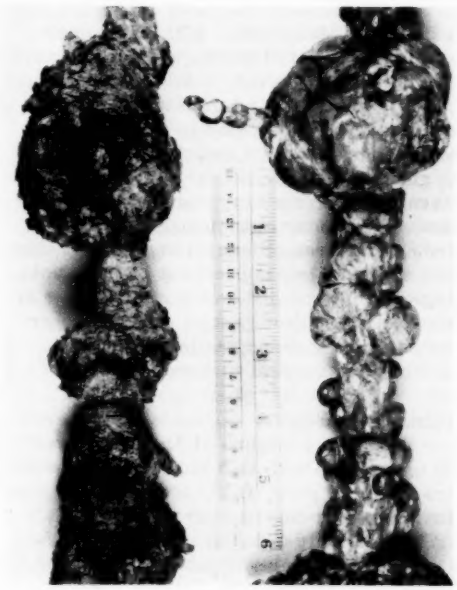

FIGURE 1. Tumors on young lodgepole pine trunks in the Big Horn Mountains, Wyoming, with and without bark.

The largest known outbreak is in the Big Horn Mountains south of highway U. S. 16 (T. 48 N., R. 86 W.). Part of the area has been logged, and it is perhaps only due to removal of disease-free trunks that more than 20% of the residual stand is tumorous. In most parts of the cutover, lodgepole reproduction is now free of tumors, but on a few acres all the seedlings are infected. One subalpine fir (Abies lasiocarpa) bearing about 300 tumors was found in a group of tumorous lodgepole pine. Engelmann spruce (Picea engelmannii) and limber pine (Pinus flexilis) in the stand appeared healthy, as did all firs but this one.

Two Shoshone National Forest outbreaks southwest of Lander, Wyoming (T. 32 N. and T. 30 N., R. 101 W.) were notable for numerous tumors on limber pine occurring wherever the tumorization on lodgepole pine approached 100%. Tumored firs were noted also; the few spruces present in the stands were healthy.

In Yellowstone National Park the diseased trees are more easily accessible than elsewhere. One large infestation occurs along U.S. 20 west of West Thumb; in it about two dozen tumored firs were found among the thousands of badly deformed lodgepole, but the spruce and limber pine appeared healthy. Other infestations in the Park occur near Shoshone Lake and, according to reliable report, along the old road between West Thumb and Lake (near Yellowstone Lake).

Tumors occur in a few stands where lodgepole pine is absent or healthy. The chief example is a nearly pure Douglas-fir (Pseudotsuga menziesii) stand of a few acres' extent in Bighorn National Forest (T. 49 N., R. 87 W.), near but distinct from an outbreak on lodgepole in the same township. The tumors are similar to those on pine. The few spruce and fir in the stand were healthy.

No epidemic pine tumor diseases are known in southern Wyoming or in Colorado. However, small groups of tumorous subalpine fir have been noted, for instance near Encampment, Wyoming and Allenspark, Colorado. Epidemic tumors on spruce have not yet been collected in Wyoming, but have occasionally been seen in Colorado, for instance on Engelmann spruce south of Cimarron.

LABORATORY DESCRIPTION

Tumors on lodgepole and limber pines, Douglas-fir, subalpine fir (all from Wyoming), and Engelmann spruce (Colorado) were sectioned transversely and radially for comparison with one another and with normal tissues of the same conifers. Tumors on all species appeared similar, and shared the following characteristics: (a) modified xylem extended from near (or at) the pith to the cambium in a steadily enlarging conical zone; (b) tumor xylem cells were usually not much larger than those in healthy tissue, but 1.1 to 10.0 times more cells were produced along a given radius in a tumor than nearby outside the tumor; (c) unlike wood in rust galls, tumor xylem contained normal percentages of ray parenchyma, and was not modified by deposition of resins or other materials, nor was the bark of tumors modified. All of these observations duplicate the report of White (6) regarding tumors on Picea glauca in Maine.

It was further noted that in those lodgepole pine specimens collected in late summer cambial activity had ceased in healthy tissue but was recent or continuing in tumor tissue (as evidenced by absence or presence of living vertical cells centrad from the cambium). Possibly the tumor stimulus merely prolongs the season of cambial division rather than accelerates the rate.

A variety of staining techniques and attempted isolations on culture media designed for fungi and bacteria were ineffective in locating any pathogen in tumors.

DISCUSSION

This disease is economically significant because it lowers timber values of lodgepole pine stands on thousands of acres in the central and northern Rocky Mountains. Although tumor wood is sound, its cross grain would weaken boards cut from diseased trees, even if a tumored trunk could be safely handled in a saw carriage. As roundwood, however, tumored trunks and branches have found some use in the manufacture of novelty furniture and interior decoration at Cody and Sheridan, Wyoming. Probably the best known use of tumored pine is at the Upper Geyser Basin of Yellowstone, where "knobbled" timbers adorn the lodge and curio store.

Cause of the tumorous condition is unknown. The grouped distribution of tumors within a tree and within a stand strongly suggests infectious disease or infestation by an insect of limited mobility. Dwarfmistletoe and western gall rust frequently occur in tumorous lodgepole pine stands and have been said to cause the deformations. However, these pathogens are easily demonstrable in sections from stems that they infect; they are lacking (except by rare coincidence) in tumors. Nor do the host range and pathological anatomy of tumors match those of any known phanerogam or fungus parasite that causes swellings. That genetic phenomena are involved seems to be ruled out by the occurrence, in heavily infested lodgepole stands, of tumors on other conifers. Considerable time was spent inspecting the youngest tumors for presence of insects or insect wounds, but none were found.

With White (6) we can state that these are "not typical crown galls, ...not typical insect galls, ...and not typical irritation teratomas." Unlike the spruce tumors of Maine and western Canada, tumors in the Central Rockies seem not to be associated with salt spray, sulfur water, or any other peculiarities of the environment. Tumors occur in poor, fair, and probably good timber sites, on all slope aspects, on ridges and in bottoms, and on a variety of soil types. Tumors do seem limited with regard to altitude, but it may be only coincidence that the seven known outbreaks in lodgepole pine and Douglas-fir in northern Wyoming occur between 8000 and 9200 feet elevation (where forests extend from 5000 to 10,000 feet), and three groups of tumored trees in southern Wyoming and Colorado occur between 8000 and 9600 feet (where forests occur at 11,000 feet).

Present experiments in the greenhouse are concerned with transmission of the tumor stimulus by mechanical means, by insects, and by grafts. There have been no positive results during the first 8 months of study.

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DIFFERENTIAL SENSITIVITY TO BIPHENYL AMONG STRAINS OF PENICILLIUM DIGITATUM SACC.

Ruben Duran and Shirley M. Norman[1]

Abstract

Methods devised to separate biphenyl-sensitive from non-sensitive strains of Penicillium digitatum Sacc. indicate that striking differences in biphenyl sensitivity occur among strains of the fungus.

Spores of sensitive strains germinated in a biphenyl atmosphere about as readily as non-sensitive strains but were unable to develop beyond the germ tube stage in a continuous biphenyl atmosphere. Such strains were readily controlled with biphenyl when inoculated in lemons. Spores of non-sensitive strains under these conditions developed vigorous sporelings, abundant post-germination growth, and were not controlled with biphenyl when inoculated in lemons.

The ability to produce abundant vegetative growth in the presence of biphenyl was more important than spore germination counts in detecting biphenyl-tolerant strains.

Although their frequency of occurrence was not established, non-sensitive strains were found in five citrus-producing areas sampled in southern California.

INTRODUCTION

Each year citrus green mold, incited by Penicillium digitatum Sacc., accounts for serious postharvest decay losses of citrus fruit. Losses are common in stored fruit awaiting packing and in packaged fruit during transit and after arrival at terminal markets.

Decayed fruits are generally covered by olive-green dusty spore masses which tend to dislodge during transit and handling operations. Thus a few decayed fruits can cause considerable soilage in commercial shipments of citrus.

In 1935 Tomkins (9), using biphenyl-impregnated wrappers, showed that vapor from this chemical reduced fruit decay and fungus sporulation responsible for fruit soilage. In 1938 in a number of shipping tests from Palestine to London, Farkas (2) also demonstrated a substantial decay reduction in oranges wrapped in biphenyl-impregnated wrappers.

Ramsey, et al. (6), in making a study of the effects of biphenyl vapor on various fungi, demonstrated germination inhibition of P. digitatum spores by suspending them in drops of sterile water over biphenyl crystals. They described, furthermore, cellular hypertrophy and sharply reduced radial growth of the fungus when grown on potato-dextrose agar in the presence of biphenyl vapors.

In 1940 Farkas and Aman (3) induced biphenyl resistance in P. digitatum by exposing fungus cultures to biphenyl vapors for several weeks; in 1959 Harding (4) reported similar results. None of these workers, however, presented evidence of inherent differences in biphenyl sensitivity among strains of P. digitatum.

Rygg, et al. (8) in 1959 at Hamburg, Germany, observed startling differences in decay and soilage control among lots of biphenyl-treated lemons shipped from California.

The present work was done to determine whether strains of the fungus vary in sensitivity to biphenyl. Qualitative differences in sensitivity among 24 strains collected along coastal and inland citrus-producing counties of southern California are reported.

MATERIALS AND METHODS

In an evaluation of biphenyl sensitivity in vitro of the test strains exposed continuously to a biphenyl atmosphere three criteria were considered collectively: 1) ability of spores to germinate on artificial media, 2) ability of spores to sustain growth, that is, to produce vigorous colonies, and 3) ability of colonies to sporulate.

Since fruit decay and soilage control depend on how well biphenyl inhibits the above factors, lemons from local packing houses were inoculated with test strains unable to develop in biphenyl beyond the germ tube stage to see whether such strains could be controlled. Strains that grew well in biphenyl also were used to inoculate lemons to see if they would resist control.

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Table 1. Effects of biphenyl vapor on spore germination, radial growth, and spore production in vitro of 24 strains of Penicillium digitatum.

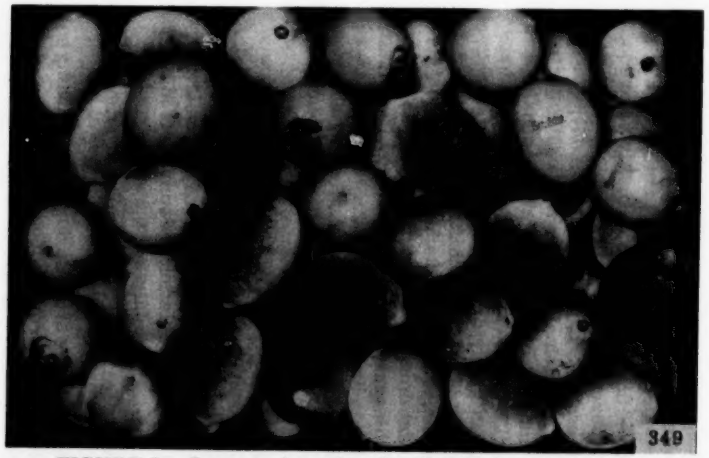
Test strain	Spore germination[a]		Sustained growth[b]		Radial growth[c] (in mm)				Spore production[d] ($X10^6$)	
					120 hours		168 hours			
	controls	biphenyl	controls	biphenyl	controls	biphenyl	controls	biphenyl	controls	biphenyl
1	+, -	-, -	+, —	— , —	24	—	38	—		
2	+, +	+, -	+, +	+ , —	25	20	45	37		
5	-, -	+, -	—, —	+ , —	—	28	—	45		
7	+, -	+, +	+, —	+ , +	22	12	40	22		
10	+, -	+, -	+, —	-*, —	23	0	44	0		
349	+, +	+, -	+, +	+ , —	24	15	43	34	3.5	1.5
350	+, +	+, +	+, +	-*, -*	22	0	43	0		
380	+, -	+, -	+, —	-*, —	24	0	44	0		
383	+, +	+, -	+, +	+ , —	21	20	38	36	4.6	2.0
391	+, +	-, -	+, +	— , —	22	—	41	—		
482	+, +	+, +	+, +	+ , +	31	30	51	47		
482A	+, +	+, +	+, +	+ , +	29	31	44	50		
741	+, +	+, -	+, +	+ , —	29	27	43	43		
777	+, +	+, +	+, +	+ , +	31	29	51	44	3.4	2.7
778	+, +	+, +	+, +	-*, -*	22	0	35	0		
787	+, +	+, +	+, +	+ , +	33	31	54	50	3.5	2.0
788	+, -	+, +	+, —	+ , +	34	30	54	50	3.5	2.3
796	+, +	+, +	+, +	+ , +	34	31	55	50	3.4	1.7
798	+, +	+, +	+, +	-*, -*	28	0	48	0		
802	+, +	+, +	+, +	+ , +	28	29	40	45	4.8	2.8
818	+, +	+, +	+, +	-*, -*	29	0	49	0		
842H	+, +	+, -	+, +	+ , —	24	22	41	40	4.4	2.7
853	+, +	+, -	+, +	-*, —	24	0	44	0		
M-6-A	+, +	+, +	+, +	-*, -*	27	0	55	0		

[a]Spore producing a germ tube overnight = +, spore failing to germinate = -.

[b]Spore producing a more or less normal colony = +, spore failing to sustain growth although germinating = -*, spore failing to germinate = —.

[c]Except where only one spore germinated and sustained growth, radial growth equals average diameter of two colonies measured from margins of advancing mycelium.

[d]Spore counts of only eight strains are given. Total spores calculated per cc of spore suspension produced by one colony. Since the spores were originally suspended in 100 cc of water, multiplying by 100 equals spores produced per colony.



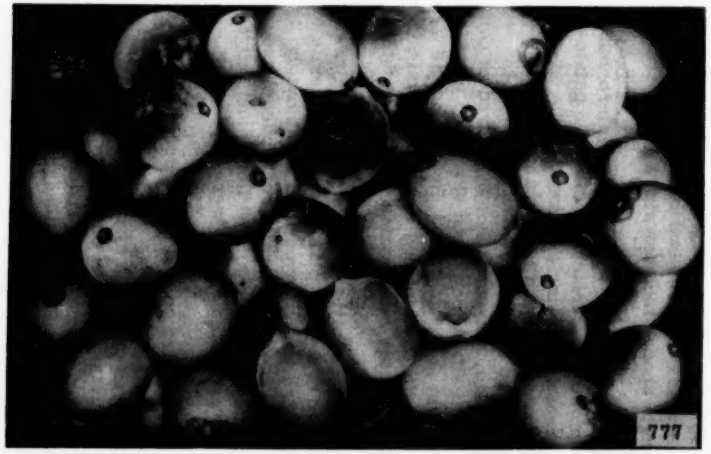


FIGURE 1. Lemons inoculated with strains of Penicillium digitatum not controlled with biphenyl. Note the copious spore-masses and aerial mycelium produced in the presence of biphenyl vapors after 1 week at 68° F. Non-inoculated fruits marked at stem ends.

FIGURE 2. Lemons inoculated with strains of Penicillium digitatum controlled with biphenyl. Note the lack of spores and limited aerial mycelium produced in the presence of biphenyl vapors after 1 week at 68° F. Non-inoculated fruits marked at stem ends. (compare with Fig. 1)

Twenty-three strains of the green mold organism collected by exposing Petri plates containing sterile potato-sucrose agar in packing houses in Orange, San Diego, San Bernardino, Santa Barbara, and Ventura counties were included in the tests[2]. The test cultures, ranging in age from 3 to 14 months, were established from single spores isolated with a Chambers micro-manipulator.

To determine the effects of biphenyl on spore germination, four spores were micro-manipulated from a monosporic culture of each test strain onto the surfaces of separate potato-sucrose agar blocks 5 mm square. Each agar block containing a single spore was placed on a sterile glass cover-slip and inverted over a Van Tiegham cell. Each test strain was thus represented by four spores. Two of the spores were treated by placing about 10 mg of biphenyl crystals in the bottom of each cell; the remaining two, without biphenyl, served as controls. The four spores of each strain in their respective cells were placed in a Petri plate containing a moistened filter paper and incubated overnight at 72° to 75° F. By placing the Van Tiegham cells over perforations in the filter papers the effect of biphenyl on spore germination and subsequent growth could be observed by direct microscopic examination with exposing the cultures to aerial contamination.

Spore germination was recorded after about 18 hours' incubation. After 48 hours, irrespective of germination, each agar block was transferred to a Petri plate containing sterile potato-sucrose agar. Each plate containing a treated spore was uncapped and immediately inverted in a biphenyl chamber measuring 3 x 3 x 2 feet. The concentration of biphenyl vapor in the chamber was produced from biphenyl crystals spread on the chamber floor, and ranged from 10.1 to about 24.5 μg per liter[3]. Plates containing untreated spores were kept in the laboratory at 72° to 75° F.

Radial growth of colonies produced by treated and untreated spores was recorded after 120 and 168 hours.

After 8 days comparisons were made of the total spores produced by colonies of eight strains (349, 383, 777, 787, 788, 796, 802, and 842-H) in the biphenyl chamber and eight corresponding control colonies. The spores from each Petri plate were suspended in 100 cc of water, containing a wetting agent, by stirring at high speed in a Waring Blendor. Spore counts of aliquots were made immediately with a Levy-Hausser hemacytometer.

Spore suspensions of strains 349, 383, 777, and 842-H were used to inoculate lemons. In these strains the treated spores that germinated produced vigorous colonies in the biphenyl chamber. Additional inoculations made with spore suspensions of strains 350, 380, 778, and M-6-A in which all treated spores that germinated failed to produce colonies in the chamber; of strains 1 and 391 in which the treated spores failed to germinate; and of strain 7 in which the spores germinated but in which subsequent growth in the chamber was slightly retarded. All fruit inoculations were made with suspensions of spores from control colonies.

The inoculations were made with a device described by Roistacher and Klotz (7), consisting of a Pexiglas container holding a spore suspension in which a circular saw blade rotates constantly. The slowly rotating saw blade carries a continuous film of spore suspension and keeps the inoculum in constant agitation. Each of the 12 strains of the fungus was used separately to inoculate lots of 50 lemons. By passing fruits singly across the protruding teeth of the saw blade (about 1 mm), lemons were simultaneously injured and uniformly inoculated. Immediately following the inoculations the lots of lemons, each with 10 uninoculated control fruits, were placed in nonvented fiberboard cartons containing two sheets of kraft paper impregnated with biphenyl, one placed on the bottom of the carton, the other on top of the fruit. The cartons of fruit were stored at 68° F and 90% relative humidity and examined after 1 week. Disease control was evaluated on the basis of suppression of fungus sporulation and decay reduction.

RESULTS AND DISCUSSION

The effects of biphenyl vapor on spore germination, colony growth, and spore production of 24 strains of the fungus are summarized in Table 1. Differences in biphenyl sensitivity among fungus strains as reflected in fruit decay and fungus sporulation are summarized in Table 2.

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[2]Also strain M-6-A kindly furnished by J. W. Eckert, California Citrus Experiment Station, Riverside, California.

[3]The concentration of biphenyl was determined by drawing 2 liters of air through a gas washing bottle with an extra coarse porosity fritted cylinder containing 20 cc of ethyl alcohol. A sample of the alcohol containing biphenyl was read at 248 mμ on a spectrophotometer against a standard curve. Concentration range based on five determinations averaging 17.94 μg per liter.

Table 2. Differential biphenyl sensitivity among 12 strains of P. digitatum as reflected in decay and fungus sporulation in lots of 50 inoculated lemons held 1 week at 68° F in nonvented cartons with two biphenyl-impregnated kraft sheets.

Test strain reaction to biphenyl[a]	Decayed fruits[b]	Fruits showing fungus sporulation	Approximate surface of fruits covered with spore-masses
Non-sensitive			
7 *	50	50	2/3
349 *	50	50	2/3-3/4
383 *	50	50	2/3
777 *	50	50	2/3
842-H*	50	50	2/3
1 **	50	50	2/3
391 **	50	50	2/3
Sensitive			
350 ***	8	3 (5 aerial mycelium)	Trace at inoculation point
380 ***	6	1 (5 aerial mycelium)	do.
778 ***	36	10 (26 aerial mycelium)	do.
798 ***	3	1 (2 aerial mycelium)	do.
M-6-A***	13	0	none

a *Treated spores that germinated produced colonies in biphenyl.
**Biphenyl effects in vitro inconclusive since treated spores did not germinate.
***Treated spores that germinated failed to produce colonies in biphenyl.
b No decay resulted in 10 uninoculated lemons included in each lot of inoculated fruit.

Since the total number of spores that germinated (treated or untreated) was about the same, strain sensitivity could not be determined strictly on spore germination counts. However, the effects of biphenyl in producing hypertrophied germ tubes afforded an early clue to sensitive strains.

From a total of 48 treated spores, 35 germinated but only 22 produced fungus colonies in a biphenyl atmosphere. In these, biphenyl retarded and reduced sporulation. Untreated spores that germinated produced normal colonies which began sporulating heavily after 92 to 120 hours. Colonies that grew in biphenyl began sporulating about 168 hours from the time of the original isolations. The effect of biphenyl in retarding sporulation was also reflected in the spore harvests. After 8 days control colonies produced about 3.88×10^6 spores per cc of spore suspension and colonies that developed in biphenyl about 2.21×10^6.

In strains where both treated spores germinated the effects of biphenyl were consistent, that is, both spores produced vigorous colonies in biphenyl or both failed to develop beyond the germ tube state. Strains that developed fungus colonies in biphenyl, for example, 7, 349, 383, 777, and 842-H, were not controlled when inoculated in lemons (compare Tables 1 and 2); conversely, excellent control was obtained with strains unable to produce colonies in biphenyl, for example, 350, 380, 778, 798, and M-6-A. Strains 1 and 391 in which the treated spores failed to germinate (probably because they were not viable) were not controlled when inoculated in lemons and proved to be non-sensitive strains.

Except for belated and reduced sporulation, non-sensitive strains are able to germinate and grow well in a biphenyl atmosphere. Apparently spores of some sensitive strains are germinable in biphenyl but can not make any appreciable vegetative growth in the presence of the fungistat.

Obviously there are striking differences in biphenyl sensitivity among strains of P. digitatum. Results show that some strains are well controlled by emanations of biphenyl when inoculated in lemons, whereas others are not controlled (compare Figs. 1 and 2).

Although this paper presents differences in biphenyl sensitivity of only 24 strains of P. digitatum, our data (unpublished) indicate that non-sensitive strains are relatively common in packing houses where they have not yet been reported as troublesome.

Information on the origin of non-sensitive strains is lacking. Since in this work cultures used to inoculate lemons were not exposed to biphenyl, non-sensitivity was not induced by previous exposure to biphenyl vapors. Whether heterocaryosis demonstrated by Baker (1) and Pontecorvo and Gemmell (5) as a means of exchanging heritable factors in Penicillium notatum Westling is responsible for the origin of strains not sensitive to biphenyl is open to conjecture at present.

Since non-sensitive strains could be introduced into new areas or their numbers increased where they currently exist, stringent sanitation practices should be followed. Decayed fruits in wastecans should be disposed of promptly; old cull piles should be removed and all other sites likely to promote fungus propagation in packing houses should be eliminated.

Because some strains of the fungus are not readily controlled with biphenyl, and from a practical point of view their existence is tantamount to a "resistance" problem, a qualitative evaluation of biphenyl sensitivity of many strains in citrus-producing areas of southern California is in progress.

Since non-sensitive strains were found in all citrus-growing areas sampled, obviously they are not limited geographically and they constitute a potential threat to domestic and export shipments of citrus fruit.

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OCCURRENCE OF XIPHINEMA AMERICANUM COBB IN SOME SASKATCHEWAN SOILS[1]

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Little is known of the occurrence of free-living plant-parasitic nematodes in Saskatchewan. To explore their possible significance to woody plants in this province, soil samples from six nurseries or orchards at Saskatoon and Indian Head were examined. Xiphinema americanum Cobb was present in 20 of the 41 samples from four localities near Saskatoon. Populations of this root-damaging nematode varied from 123 to 3362 per pound of soil in seven of eight samples from an apple orchard; 400 per pound were found in soil of a poplar stooling bed in a nursery, and smaller populations were found in samples from the root zones of apple, caragana, elm, fir, and monkshood. Ten of 36 samples from two localities near Indian Head carried populations of X. americanum. Seven hundred of these nematodes per pound of soil occurred in soil from a 48-year-old stand of Colorado spruce, 164 per pound in soil from crab-apple roots, and smaller population in soil from lilac and poplar roots.

Specimens of the plant-parasitic genera Ditylenchus, Hoplolaimus, Paratylenchus, Rotylenchus, and Tylenchorhynchus were found in trace populations from one or more of the localities sampled. It is a matter of interest that Pratylenchus penetrans was found only in soil around a Thuja recently imported from Holland by a Saskatoon nursery. In addition to the plant-parasitic genera listed above, small to moderate populations of saprophagous nematodes were found in the samples. These included species of the following genera: Acrobeles, Acrobeloides, Aphelenchoides, Aphelenchus, Chiloplacus, Diplogaster, Discolaimus, Dorylaimus, Mononchus, Panagrolaimus, Pungentus, Rhabditis, and Tylenchus.

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[1]Joint contribution from units of Research Branch, Canada Department of Agriculture; Forest Nursery Station, Indian Head, Saskatchewan (No. 12) and Experimental Farm, Saanichton, British Columbia (No. 180).

BACTERIAL SCAB OF TOMATO IN PUERTO RICO

J. Enrique Pérez[1]

Tomato fruits, and plants bearing fruits with lesions highly suggestive of scab spot, as well as leaves showing brown leafspot lesions, were brought to our laboratory from the localities of Jayuya and Isabela in Puerto Rico.

From the diseased fruits and leaves pure cultures of a gram-negative, capsulated bacillus which gave rise to yellow colonies on nutrient agar were obtained. One of the isolates was inoculated on tomato plants and fruits of the Marglobe variety, resulting in typical lesions of scab spot.

Cultural characters, fermentation reactions, and serological tests showed the organism to be very similar to two type cultures of Xanthomonas vesicatoria from the United States and England.

A more detailed account of this previously unreported bacterial disease in Puerto Rico is to appear elsewhere[2].

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APHANOMYCES RAPHANI KENDRICK IN RADISHES IN OREGON

Robert M. Hosford, Jr.

In recent years red radishes in some fields around Portland, Oregon have become severely affected by a condition characterized by discoloration, distortion and rotting of the root. A fungus isolated from affected roots and seedlings and identified as Aphanomyces raphani Kendrick, the cause of black root of radish, has been proved to cause the Oregon disease. This is believed to be the first report of this fungus in the Pacific Northwest (1, 2).

Soil analysis of a field in which the disease was severe indicated no adverse conditions except a high lime requirement (3 tons per acre) and a boron level of only 0.86 ppm. Because the symptoms of the disease were similar to those of boron deficiency, plots of radish seedlings in the disease area were sprayed with Solubor alone and Solubor with chelates of iron, zinc, magnesium or copper. The Solubor was 20% boron and was applied at rates of 12.5 pounds/acre or higher. No treatment affected the severity of the disease, but all treatments caused stunting of the radishes.

August 15, 1957, chloropicrin at the rate of 35 gallons/acre was applied to the field. It was placed 6 to 8 inches deep by drills 8 inches apart on a shank injector. The following crop was almost completely free from disease, but a subsequent crop planted in October 1957 was severely diseased. In April of 1958 radishes grown in treated soil in a greenhouse were severely diseased. On April 16, 1958 the field was again treated and planted to radishes. The radishes were severely diseased. Chloropicrin seemed to have caused an initial reduction in the disease (August 15, 1957), but the reduction was short lived (October 1957) and not repeated (April 16, 1958). Use of chloropicrin for prevention of radish black root is therefore of questionable value.

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